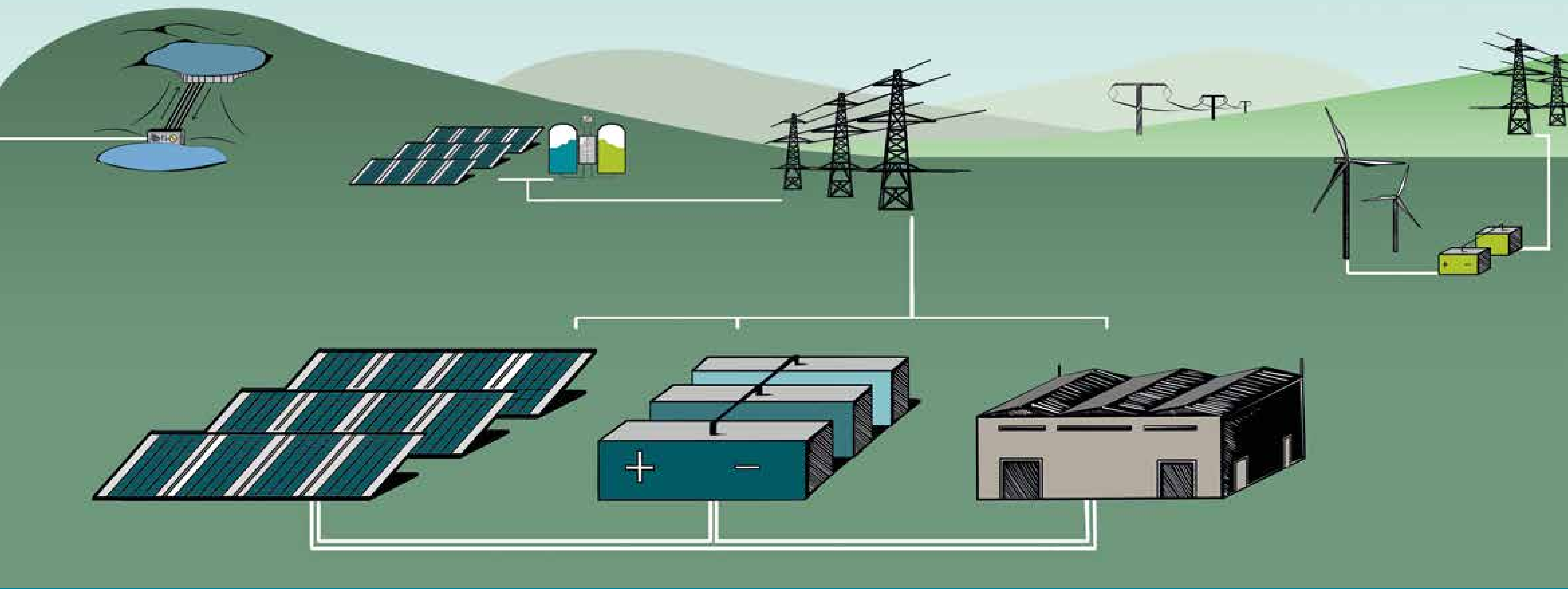
Energy Storage: The Next Wave

Growth prospects and market outlook for energy storage

regen transforming energy



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Green Hedge develops, builds and operates battery energy storage projects. It is majority-owned by cleantech private equity firm Zouk Capital. With offices in London and Bath, Green Hedge was established in 2010 and has developed and realised 20 solar farms across the UK with a total installed capacity of 150 MW.

Green Hedge pioneered the Energy Barn™ concept of battery energy storage housed in steel-framed buildings. The company has a large and diversified portfolio of grid-scale battery energy storage projects, both in front of meter and behind the meter applications for large commercial and industrial customers.

TLT has been involved in the clean technology sector for over 20 years, advising on a wide range of projects for a variety of different organisations from high growth entrepreneurial companies to large utilities, banks and equity investors. We have been instrumental in tackling the legal issues around energy storage projects be that stand-alone projects, looking at commercial models for co-location or developments in new markets such as behind the meter. We have also advised government departments in relation to the implementation and operation of energy efficiency and renewables policy. TLT's experienced legal team is one of the few that can provide UK-wide legal advice, supporting projects across all UK-legal jurisdictions. Our dual qualified lawyers are also able to support projects in Republic of Ireland.

Triodos Bank is a global pioneer in sustainable banking using the power of finance to invest in projects that are good for people and the planet. Triodos uses its €13.5 billion in assets to create social, environmental and cultural value in a transparent and sustainable way. With UK operations based in Bristol, Triodos Bank has branches in the Netherlands, Belgium, Spain, Germany and an agency in France. The bank has over 20 years' experience of investing in renewable energy. As part of its mission to make money work for positive social and environmental change, it has built up a strong track record in this area, having funded hundreds of sustainable energy projects across Europe - ranging from community energy groups to more established developers.

Vattenfall wants to be fossil fuel free within a generation. Vattenfall's zero carbon operations in the UK are a cornerstone of this ambition. Since our arrival in late 2008 we have grown a portfolio of almost 1GW of energy generation.

Vattenfall is progressing the largest co-located battery and wind farm project in the UK at the 228 MW Pen y Cymoedd Wind Energy Project, a 22 MW battery storage system which will provide Enhanced Frequency Response (EFR) services to National Grid.

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Specifically Regen would highlight that in the rapidly changing sector of energy and energy storage, all references given to technology performance, financial figures, costs and revenues must be considered as illustrative and subject to significant variance and uncertainty.

While Regen has sought industry and third party input to inform the report, this report has not been subject to independent verification. All opinions and forward projections contained in the report are those of Regen, and do not represent the views of any third party or sponsor organisation unless specifically ascribed.

Inevitably the report draws on previous reports and published material which cover the same ground. We have referenced those where appropriate within the document and in the further reading section but apologise in advance if, in the interests of readability, we may have omitted to reference appropriately.

Readers of this report are encouraged to use their own judgement and research in assessing the energy storage market opportunity. We would welcome feedback and comment on any aspects of the report and look forward to continuing an active debate with our industry colleagues.

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Introduction

The UK energy system has been transformed in recent years by the growth of renewable energy and a shift to more decentralised generation connected to the distribution network.

As the transformation towards low carbon, smarter and more decentralised energy continues, the importance of flexibility in the system has greatly increased.

This has been recognised by the UK government,[1] the energy regulator Ofgem, system operators and by investors in the energy industry. Energy storage is seen as both a disruptive technology, changing the way energy markets work, and a key enabler in the transition to a smarter cleaner energy system.

In 2016, Regen published "Energy Storage - Towards a commercial model"[2] which considered how the storage market might develop. Since then, Regen has worked closely with developers, network operators, finance companies, legal advisers and policy makers to better understand the emerging storage market. We have witnessed the growing interest and market activity from technology providers, developers and investors, through to energy users, community groups and homeowners, which has now reached the mainstream media.

As with any new market, there is an inevitable risk of hype overtaking reality. Stepping back from the headlines, it should be recognised that some elements of storage have been around for some time, pumped hydro for instance, while we are still at a relatively early stage of commercial development for new technologies. The number of actual new projects installed is still relatively low and, as this paper explores, the commercial models that could support investment in storage projects are just beginning to take shape.

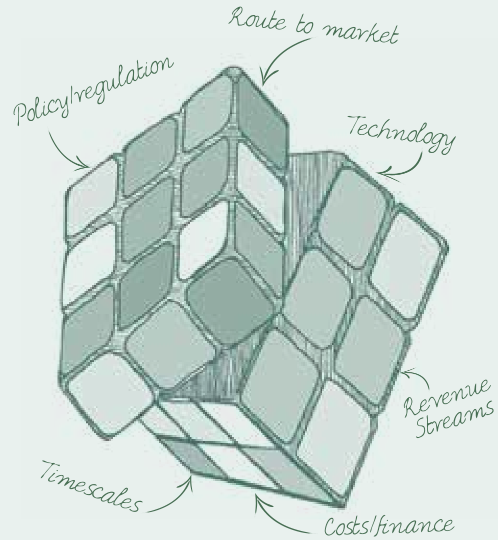
> **Beyond the hype, our assessment is that energy storage is in a strong position, with over 500 MW of commercial scale projects in the pipeline, new projects being completed and an unprecedented level of interest from developers and investors.**

There have been mixed policy messages, including the decision to reduce embedded benefits for distributed generators and the proposal to de-rate storage in the capacity market, however, as this report highlights, storage is now firmly on the government's energy agenda and as a lynchpin of its wider low carbon industrial strategy.[3]

The aim of this paper is to look beyond the current pipeline of projects to explore the next wave of energy storage and how the market may develop - looking in more detail at the challenges and growth opportunities, and focusing on the benefits of co-locating storage with generation and onsite demand.

Energy Storage - Towards a commercial model

In 2016 Regen published its first energy storage whitepaper, where we discussed the roles storage can play in a changing energy system and an analysis of emerging storage business models. We likened the storage market to an unsolved Rubik's Cube™ - which would need the alignment of technology, regulation, policy, costs and revenue streams for storage to deliver its full potential.



The paper identified a number of potential business models that have since been developed:

1) **Response service:** Providing high value frequency response services
2) **Reserve service:** Providing backup reserve services (STOR, Capacity Market)
3) **Commercial and industrial:** Located 'behind the meter' with high energy users, avoiding network charges and maximising onsite generation
4) **Generation co-location:** With variable generation to price/time shift or to peak shave generation to avoid grid curtailment
5) **Domestic and community:** Maximising own use of small generation (i.e. rooftop PV)
6) **Energy trader:** Aggregating storage to target price arbitrage or local supply models

This paper builds on this publication, exploring the potential next wave of storage projects and investigating the benefits, feasibility and potential of storage co-location and co-operation.

Energy storage: a vital part of a flexible energy system

The evolution of the UK system continues to accelerate, with power flows in our networks becoming more variable and dispersed, a Great Britain capacity margin that is becoming more difficult to calculate[4] and an increasing volume of distributed generation connecting to our networks. So far, the system has coped, even as renewables now approach 30 per cent of electricity generation, but across the industry there is a recognition of the intrinsic need for flexibility, which will help to manage the flow of power on the network, reduce system costs and improve overall resilience of supply.

Energy storage continues to be cited by many as one of the key enablers of flexibility. In large part this is because, although capital costs are still high, energy storage (particularly batteries) can support a wide variety of operational functions and valuable services.

- **Response:** The ability to respond quickly (milliseconds to minutes) to grid, frequency and/or price signals.
- **Reserve:** The ability to store and discharge energy when needed
- **Price and time shift:** The ability to shift energy from lower to higher demand and price periods.

For the purposes of this paper, energy storage is predominantly referencing electricity storage. The role of heat storage could be significant in the wider UK energy picture, but is outside the scope of this paper.

An industrial strategy:

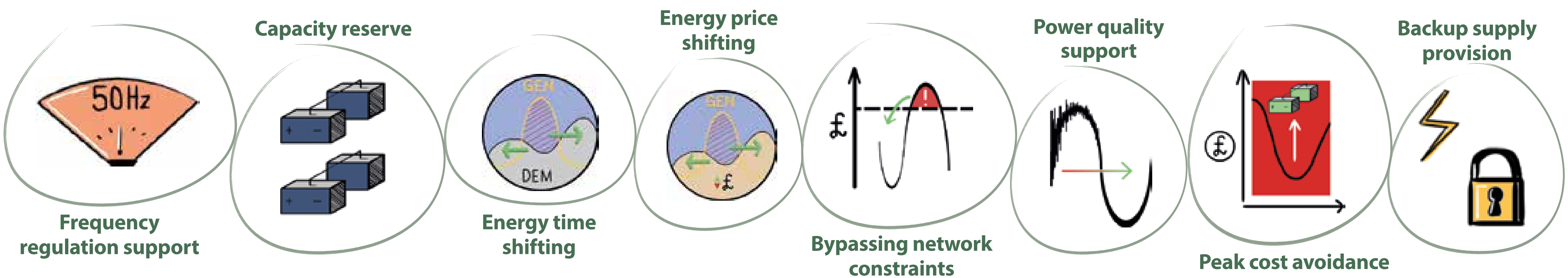
Prospects for research into energy storage technologies

In January, the Secretary of State for Business Energy and Industrial Strategy (BEIS), Greg Clark, launched an industrial strategy green paper, a consultation discussing the post-Brexit industrial strategy for the UK. Within this paper were commitments to minimising business energy costs, reviewing the options to achieving decarbonisation – including the still pending Emissions Reductions Plan – and the aspiration to ensure smart meters are in all homes and small businesses by the end of 2020.

One of the most positive moves was the ambition to instigate a research institution to focus on researching battery technology, energy storage and grid technology. This evolved into the creation of the Faraday Challenge Fund, which closed to new applications in September 2017.

This round of research funding is hopefully the first of many incentives to drive improvements in capabilities and reduce the costs of energy storage technology.

The benefits storage can provide



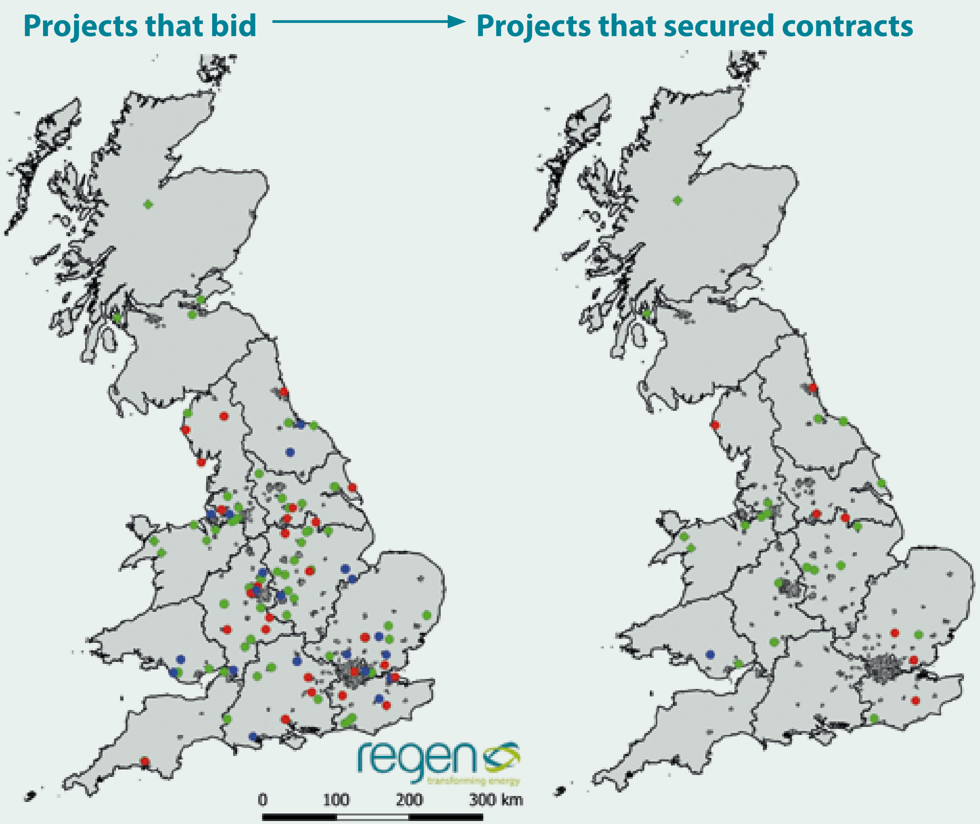
Growth of the energy storage market

To date there is an estimated 3 GW of network scale storage capacity operational in the UK. Building on a legacy of transmission connected pumped hydro systems,[5] a number of demonstration and trial projects and new battery storage systems are beginning to connect at the distribution level.

The 2016 Enhanced Frequency Response (EFR) and Capacity Market (CM) auctions showed a notable volume of storage projects committing to both programmes, with some 489 MW of storage capacity successfully bidding/pre-qualifying and going on to win contracts. These are set to connect and come online in the next two to three years.

Our analysis[6] shows that the current wave of new storage projects is dominated by solid-state battery systems that are predominantly to be connected to the distribution network. Some of the key locational factors for storage projects include access to grid capacity and the availability of low cost and accessible land. These factors support the view that the current wave of storage projects has been driven by the availability of higher value grid auxiliary services, such as frequency response and other network balancing service contracts. The geographical spread of projects bidding into the EFR and CM shows that there are fewer projects on the peripheries of the network, where there are low cost grid connection options. This picture is beginning to change as project developers begin to target co-location with generation business models, and to locate storage behind the meter of higher energy users and to support remote or island communities.

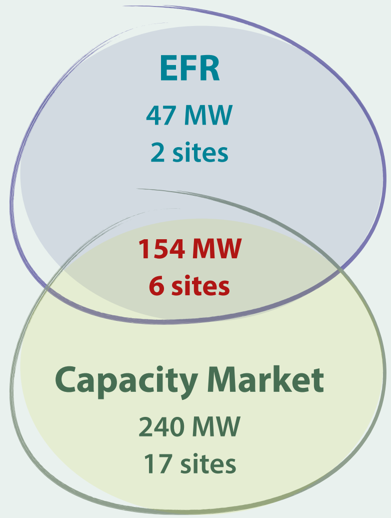
Summary of energy storage projects in the Capacity Market and Enhanced Frequency Response (EFR) programmes - 2016



Urban area
Battery storage
Capacity Market
Enhanced Frequency Response
Both Enhanced Frequency Responce and Capacity Market
Hydro storage
Capacity Market

Total winners

489 MW
26 sites



These figures are from Regen's analysis of the available data and are indicative only.

New applications for connecting storage: an unprecedented interest

Many of the UK Distribution Network Operators (DNOs) have seen a surge of interest in new connection enquiries for energy storage systems, with some DNOs quoting gigawatts of enquiries within their licence areas.[7]

Many enquiries have been speculative, yet still there is a significant volume of storage projects progressing through to an accepted connection offer. Across nine of the 14 licence areas, some 114 storage projects, totalling over 2 GW of capacity, have either accepted connection offers or have gone on to connect and bring their project online. Projects fall away at each stage of the connection process (enquired, offered, accepted, connected) as developers look for sweet spots of capacity in the network, as well as hedging the potential to secure flexibility contracts.

How the DNOs are responding

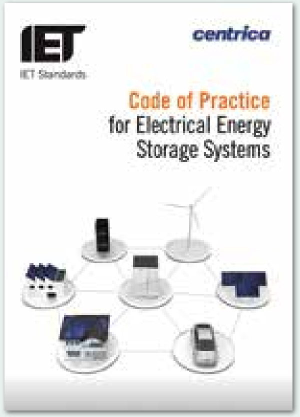
DNOs are seeking to understand how storage assets will interact with the distribution network, the impact that they will have on energy flows as well as the potential benefits and services that storage can provide to support power quality and load balancing. This is especially important on the low voltage network.

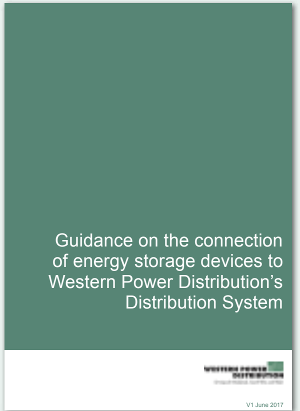
With the support of National Grid and the Energy Networks Association, DNOs are looking at a number of aspects of energy storage future growth scenario planning, operational profiling, accessing low voltage network data, developing new commercial models (as part of the transition from DNO to Distribution Service Operator (DSO), as well as new codes of practice and connection guidelines.[8 9 10]

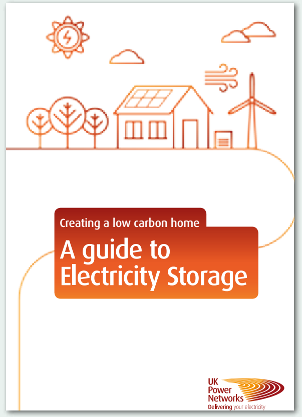
DNO storage connection data

DNO	Connection status	No. sites	Capacity (MW)
Western Power Distribution – Serving the Midlands, South West and Wales	**Enquiries**	**91**	**1,664**
	Offers	97	1,747
	Accepted	**77**	**1,275**
	Connected	**4**	**26**
	Source: WPD Generation Capacity Register (Oct 2017)		
UK Power Networks	**Accepted**	**15**	**376**
	Connected	**0**	**0**
	Source: UKPN Contracted Connections Register (Mar 2017)		
Northern Powergrid	**Accepted**	**17**	**625**
	Connected	**1**	**2.6**
	Source: NP Grid Contracted Capacity Register (Oct 2017)		

Storage guidance documents







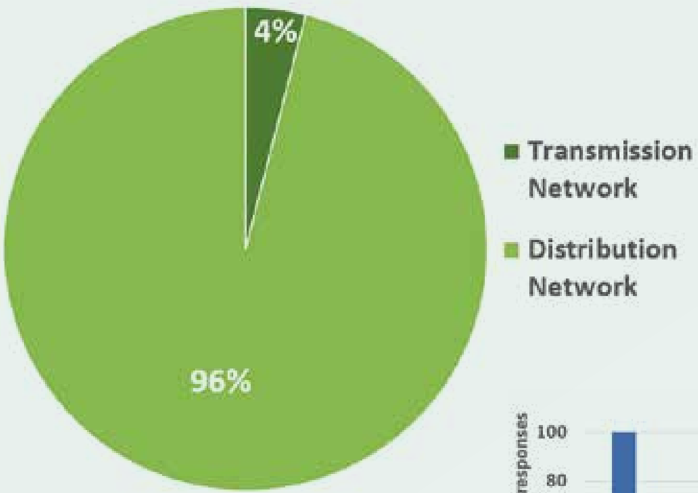
Understanding growth

WESTERN POWER DISTRIBUTION
Serving the Midlands, South West and Wales

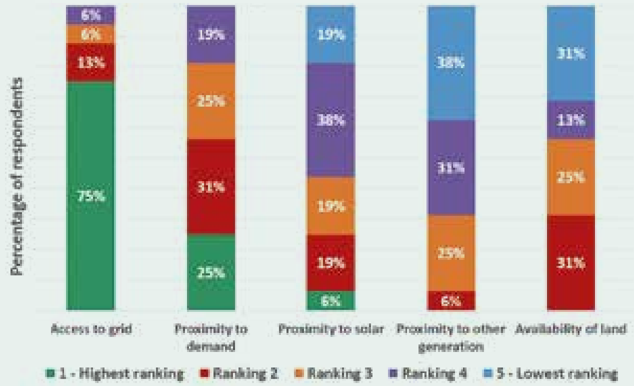
As an example of how DNOs are responding to the challenge, WPD, working with Regen, issued a consultation[6] on storage growth scenarios and operating modes this summer. This consultation sought to understand the potential scale of storage growth, the type of storage assets, their business models and technical characteristics, and their typical modes of operation.

WPD energy storage growth scenarios and operating modes consultation

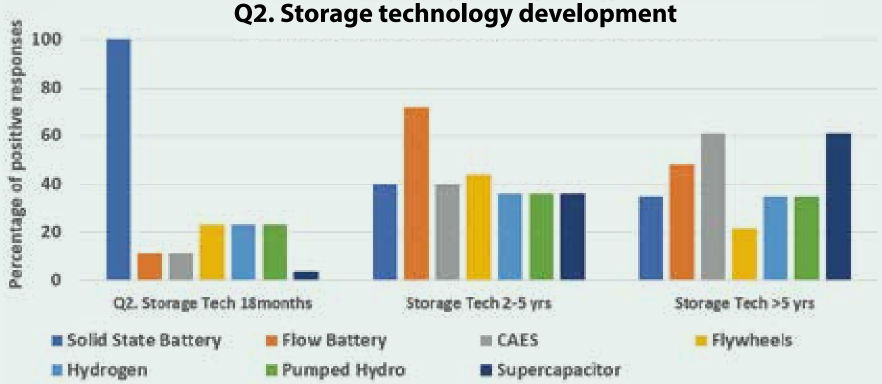
Q5. Storage connected on which network?



Q4. Rankings of locational factors



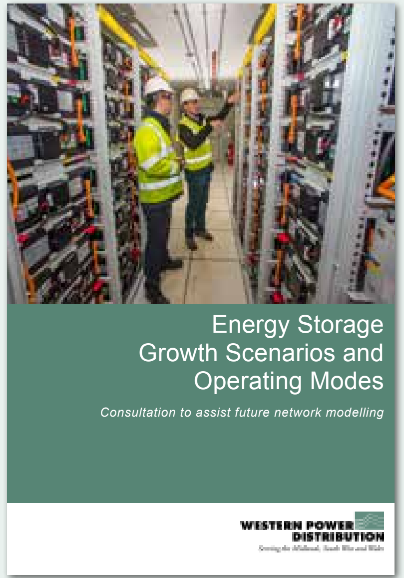
Q2. Storage technology development

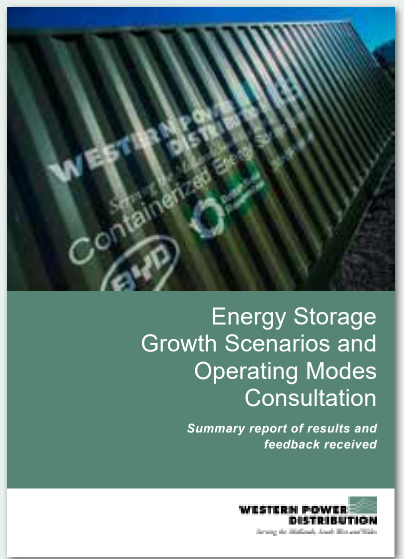


Q2 What energy storage technologies do you think will be deployed?

Q4 How would you rank the key factors determining the location of storage projects?

Q5 Which network do you believe will see the most connected storage capacity?





Future growth scenarios for storage

Projecting the potential growth of energy storage is difficult, due to the number of factors that still need to be aligned before there is deployment at scale.

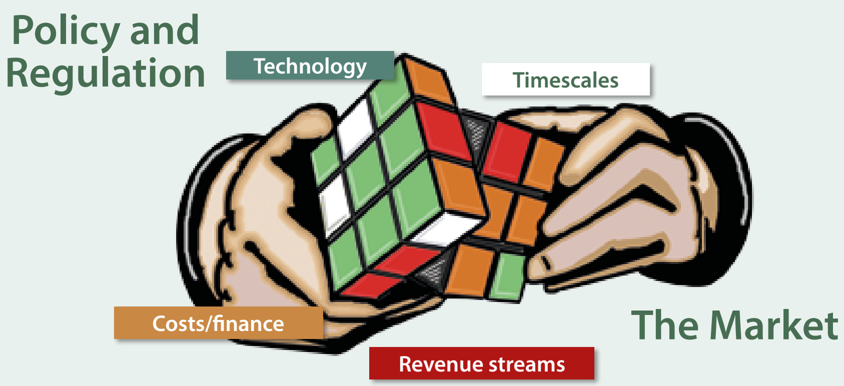
Several projections have been made:

- Regen's 2016 analysis suggested that the storage market could grow to between 10-12 GW (24-40 GWh) by 2030. Even higher growth could be achieved, but this will depend on the degree to which the value of storage is cannibalised by its own growth and that of other sources of flexibility.
- The latest National Grid Future Energy Scenarios (FES)[11] analysis includes potential high growth scenarios for storage to reach 8.6 or 8.9 GW by 2030 under a Two Degrees and Consumer Power scenario.
- Other analysis, including modelling conducted by Imperial College on behalf of the Committee on Climate Change[12] has projected higher levels of storage deployment as the requirement for flexibility services grows.

Wave 1 (Now-2020)	Wave 2 (Early 2020s)	Wave 3 (Mid/late 2020s)
Response services driven by EFR and FFR markets	Generation co-location and behind the meter models become viable	Expanded market as new business models are developed – storage becomes ubiquitous

Business model	High growth	Slow growth	Possible stretch*
Response services	2 GW	0.5-1 GW	2-3 GW
Reserve services	3-4 GW	2-3 GW	4 GW
High energy users	2-4 GW	0.5-1 GW	5 GW
Domestic and community	1-2 GW	0.5-1 GW	3 GW
Generation co-location and energy trader	2 GW	0.5-1 GW	4 GW
Total market by 2030	10-12 GW 25-40 GWh	4-5 GW 6-13 GWh	15 GW 50 GWh

* at very high growth levels the risk of revenue cannibalisation increases



Predictions of the potential growth of energy storage have varied widely. High growth scenarios have focused on key enablers that could make storage a ubiquitous technology:

- Rapid technology development and cost reduction
- Increasing value of flexibility and smart systems
- Regulatory and system change opening new markets
- Government support for innovation as part of its industrial strategy.

Lower growth scenarios have tended to emphasise that:

- Regulatory change is still needed and in some areas, such as the reduction in embedded benefits, is working against storage growth
- Technology is still expensive
- Competition from other sources of flexibility and from the growth of storage itself, i.e. cannibalisation.

Storage asset scales

The generic business models outlined in Regen's previous storage publication describe and outline commercial drivers for classes of storage assets. In addition to these, the diversity and rapid evolution of the energy storage market within these business models has created some segmentation in the scales of storage assets.

We have characterised these into three main categories:

Domestic storage
Typical scale: 1 kWh – 30 kWh

A number of home scale/wall mount battery storage products are available, with some element of modular connection. Costs per kWh are high at the domestic scale, not benefitting from economy of scale. Prime drivers for the domestic storage market are to enable those with domestic scale generation (almost entirely rooftop PV) to increase the self-use of generation, time-shifting daytime PV generation with early evening household consumption. The potential for a home battery to be used in the case of a power cut is also of value to a domestic customer.

Key operating modes:
Maximising self use of onsite generation
Mains back-up / UPS services

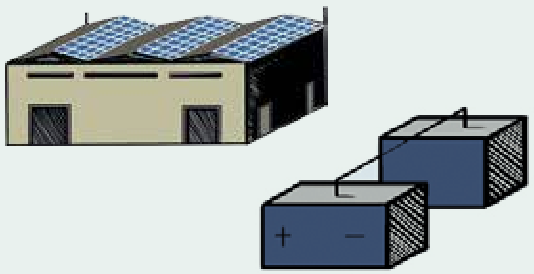
Commercial and Industrial (C&I) storage
Typical scale: 30 kWh – 1 MWh

Behind the meter storage on C&I sites is potentially suited to medium scale storage assets that align with the peak or average demand of operational load on site.

These may give rise to storage products that are designed specifically to be installed within industrial sites, using potentially similar containerisation to gridscale projects.

C&I storage assets will be optimised to enable the avoidance of peak network charges and maximising self use of generation if present on site.

Key operating modes:
Network peak charge avoider
Cost sensitive self-use of onsite generation
Mains backup / UPS services

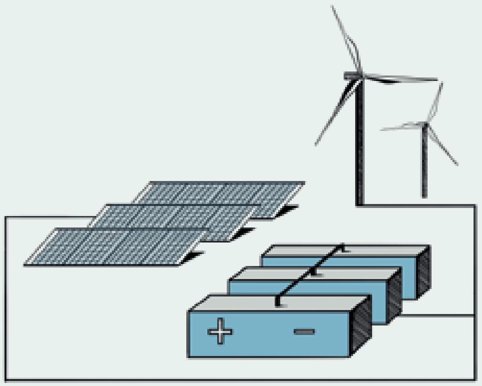


Grid scale storage
Typical scale: 1 MWh+

Standalone or grid scale storage assets are much larger in scale, potentially as multiple containerised storage units located and connected together.

This scale of asset could be targeting dedicated response and/or reserve services, or interacting with co-located standalone generation capacity, to enable additional revenue streams or bypass constrained connection capacity.

Key operating modes:
Network auxiliary services
Balancing services
Generation time and price shifting
Price arbitrage



Electric vehicles and vehicle-to-grid considerations

The rapid development of electric vehicles (EVs) is a disruptive shift that will have profound implications for the development of battery technology and for successful energy storage business models.

National Grid's FES 2017[11] outlines a low growth scenario of 6.7 million and a high growth scenario of 25.1 million EVs by 2050, translating to an EV peak demand range of 5.5 GW to 17.7 GW by 2050.

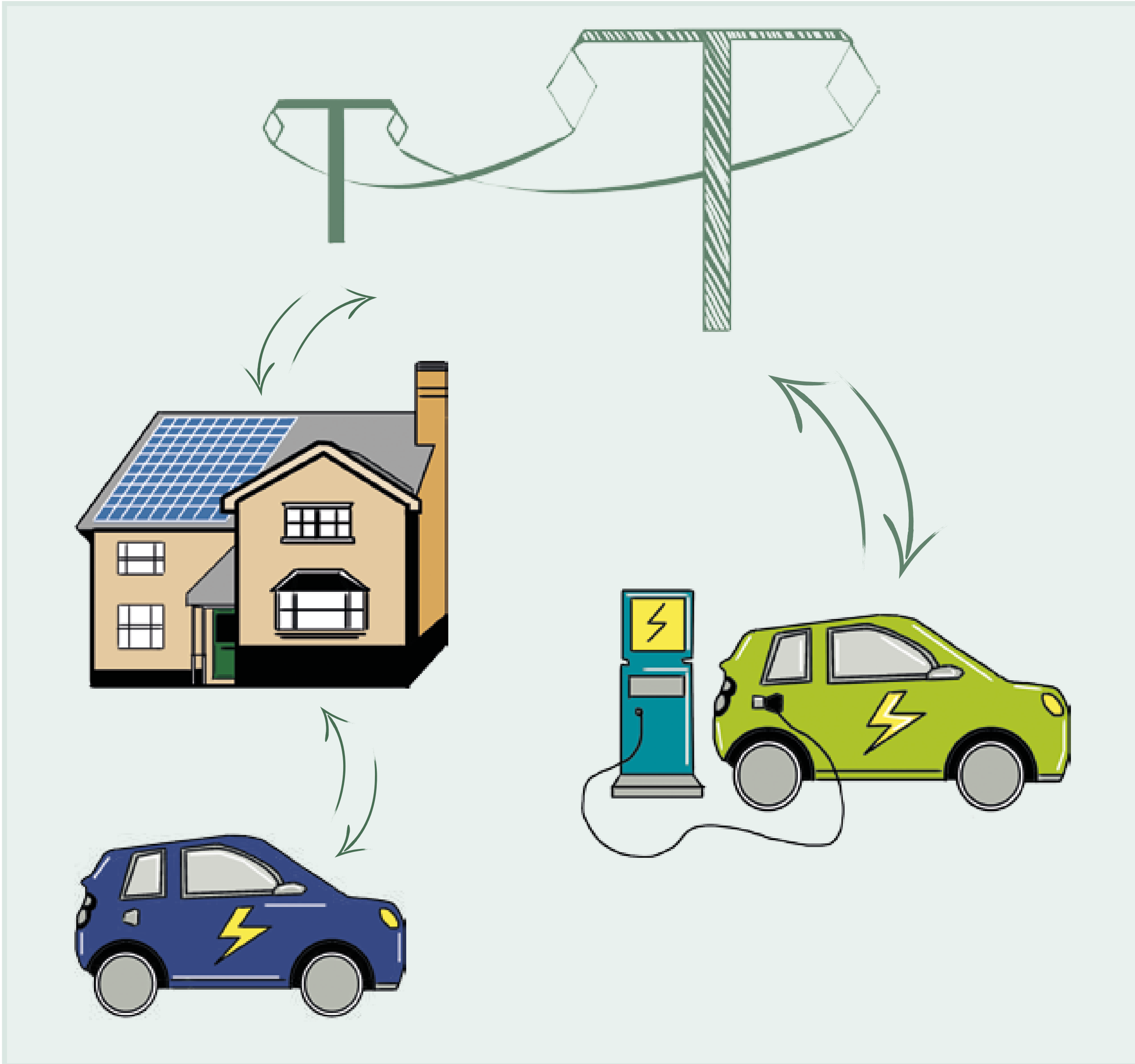
This huge market for batteries will drive research and development into battery technologies, bringing down costs and improving performance in stationary storage applications as well as vehicles.

However, if vehicles can provide vehicle to grid (V2G) services this will clearly impact on the value streams that stationary batteries are likely to be targeting.

The opportunity for system operators to tap into a dispersed reserve of EV battery banks is seen by government,[13 14] academic research bodies[15 16] and the industry as a potential opportunity to provide flexibility and support to the energy system. We are already seeing some early services come forward with energy suppliers in partnership with vehicle manufacturers offering EV tariffs based on the ability to control battery charging and sell services back to the grid.

However, this remains very early days for V2G services. The electricity stored in a car will have to be purchased at retail price and so the value for returning it to the grid will need to be significant to make this viable.

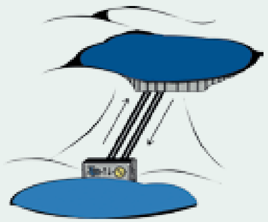
Regen will be looking into these issues over the coming months in our next paper.



Energy storage technologies – market readiness

The opportunity for innovation, and the scale of research and development activity, should mean that the cost of storage capacity technology continues to fall. Auxiliary components, including balance-of-plant such as power control and conversion equipment, offer large economies of scale but generally less opportunity for innovation. This dynamic means that, while at present high power/low capacity projects are more financially viable, as storage capacity element of costs fall, higher capacity and longer duration projects will become more prevalent.

In our 2016 study, Regen conducted a review of energy storage costs based on feedback from developers and supply chain companies targeting the EFR and Capacity Market auctions of that year. Already, based on anecdotal evidence and the result of those auctions, it is estimated that battery energy technology costs may have fallen by 10-20 per cent.

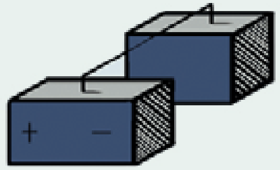


Pumped hydropower

Description: A closed loop system of pumping water to higher ground at low cost times (charge) and releasing it through hydro turbines to generate electricity when required (discharge).

These are traditionally large in scale due to the need to be sited with bodies of water separated by both distance and head – difference in vertical height.

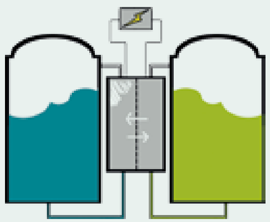
Current market viability: Strong, but requires high capital investment
Around 2.7 GW of pumped hydro has been deployed and utilised on the transmission network for many years. The potential to deploy more will depend heavily on viable sites and ongoing business models for pumped storage as capital intensive projects. Smaller scale pumped storage could be an area of growth.



Solid-state batteries

Description: Electrochemical based storage with a variety of chemistries available (NiCd, Li-Ion, NiMH, Pb-SO_4, $NaNiCL_2$, Li_2-TiO_3). Battery cells are fundamentally modular in nature, with the ability to increase capacity (MWh) by simply linking up extra cells. Batteries are quick to operate, suiting rapid response services very well.

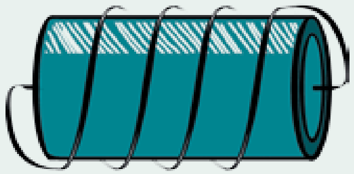
Current market viability: Strong, for flexibility services
Solid-state batteries are widely known as the current dominant energy storage technology to be considered and deployed, due to the modular nature, rapid response and flexible control. Limitations around full discharge, causing performance degradation over time, are being addressed as battery technology develops.



Flow-state batteries

Description: Electrolyte based storage with a variety of chemistries available (Redox, Vanadium Redox, Fe-Cr, $ZnBr_2$). One of the biggest advantages of flow-state batteries is that they can be almost instantly recharged by replacing the electrolyte liquid.

Current market viability: Strong, for longer duration storage
Flow-state batteries have higher upfront costs than solid-state batteries, but have longer working lives. This presents challenges in the domestic market, but several companies now see the opportunity for these batteries on a commercial scale or co-located with commercial generation.[17]



Flywheels

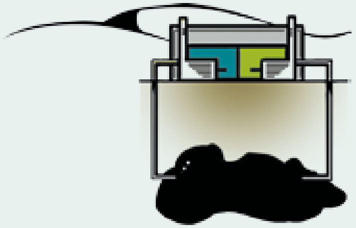
Description: Flywheel energy storage systems store energy in the form of kinetic energy by using electricity to turn a spinning mass at the centre of a flywheel, in a vacuum. When electricity is required, the spinning flywheel can be used to turn a device similar to a turbine, generating electricity.

Current market viability: Medium, but strong for specialist applications
Usually used for short term, high power applications such as frequency regulation and balancing services. Several utility-scale flywheel energy storage facilities are in operation globally, with capacities up to 20 MW for up to 15 minutes operation. Cost effectiveness is being improved by modular system solutions.

Supercapacitors

Description: Used in applications requiring high power, rapid charge/discharge cycles, as they deliver charge much faster and over many more cycles than batteries, but store less energy per unit mass. Supercapacitors are used to smooth intermittent power supplies, e.g. in wind turbines or in EVs for regenerative braking.

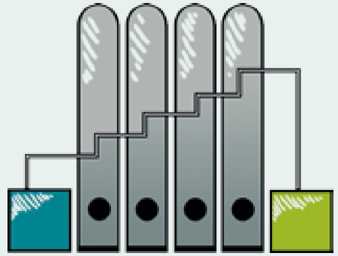
Current market viability: Medium, but strong in conjunction with other storage technologies
Supercapacitors and ultracapacitors are at present largely co-located with battery storage or renewable energy generation, performing fast response functions, extending battery lifetime and smoothing output. For utility scale storage, supercapacitors by themselves are not yet a viable solution.



Compressed Air Storage (CAS)

Description: Similar to pumped hydro storage systems, but instead of pumping water to higher ground, air is compressed, during periods of low prices and then stored under pressure. Air is then heated and expanded to drive a turbine and generate electricity. Advanced Adiabatic CAES also stores the original heat which is lost as the air is compressed and then uses this heat to re-expand the compressed air, thus eliminating the need for external heat input.

Current market viability: Developing, but requires high capital investment
Compressed air storage facilities currently require large underground caverns as a storage medium and therefore cost hundreds of millions of pounds to construct. Only a handful of large scale projects are installed globally, with capacities up to 330 MW.[18] Several start-ups are attempting to build lower capacity cost-effective systems which use above ground tanks as a storage medium.



Other air driven storage

Description: Two other technologies offering air driven storage: Pumped Heat Electrical Storage (PHES) and Liquid Air Energy Storage (LAES).

LAES: A long duration, large scale energy storage technology which works by compressing and liquifying air and storing it in an insulated low-pressure tank. Heating this liquid through a high-pressure environment creates a high-pressure gas which can then be used to drive a turbine.

PHES: Electrical energy is used to drive a system similar to a heat pump, which transfers energy from a cold store to a hot store consisting of gravel. As the hot store cools, the pressure increase, drawing in air from the cold store. This transfer of air is used to generate electricity.

Current market viability: Developing
Currently in the early commercial stage and being tested by Isentrophic Ltd (PHES) and Highview Power (LAES) in the UK.

Hydrogen energy storage

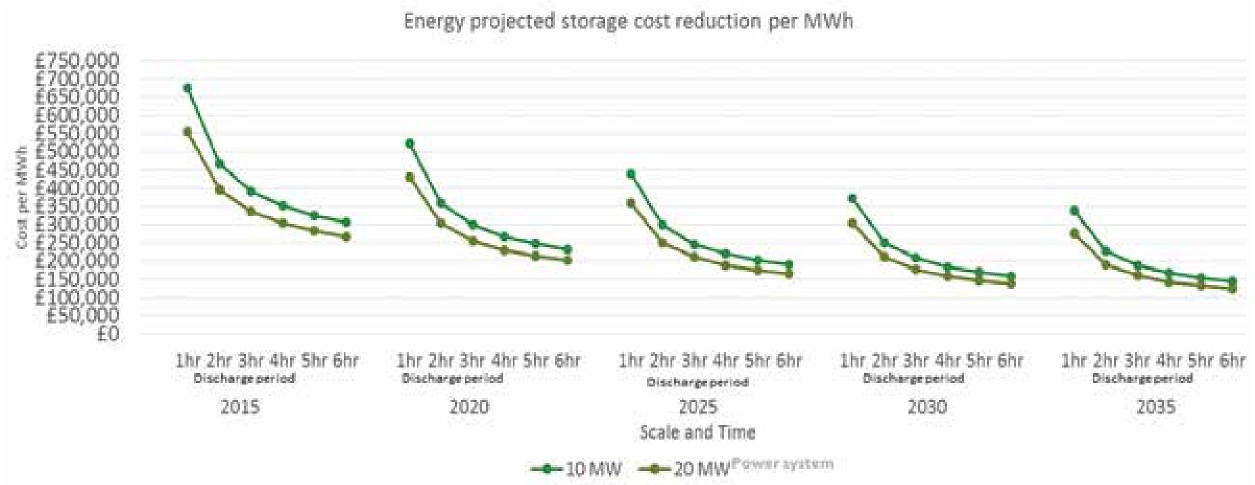
Description: The conversion of electricity into hydrogen through electrolysis, which is then stored under pressure, and converted back to electricity when needed. Hydrogen storage can be on a medium scale in large surface tanks, or on a large scale, stored underground in salt caverns. The hydrogen can then be used in gas power plants or in hydrogen fuel cells.

Current market viability: Medium, with several potential market applications
A limiting factor in hydrogen energy storage is that round trip efficiencies are currently around 30 to 40 per cent. Despite these low efficiencies, interest in hydrogen energy storage is growing because of the higher capacities when compared to batteries, pumped hydro and CAES. Large scale hydrogen in salt caverns is an established technology, but smaller scale, more cost competitive options are still in the demonstration stage.

Energy storage cost reduction

Battery storage costs have continued to fall. However, if storage is to play its full potential role in a future smart and flexible energy system, storage costs still need to fall significantly.

Different storage technologies have differing potential for cost reduction, depending on their maturity and applications they are best suited to. The role of solid state batteries in electric vehicles, for example, has attracted huge investment which is leading to rapid cost reductions.



Cost reduction potential

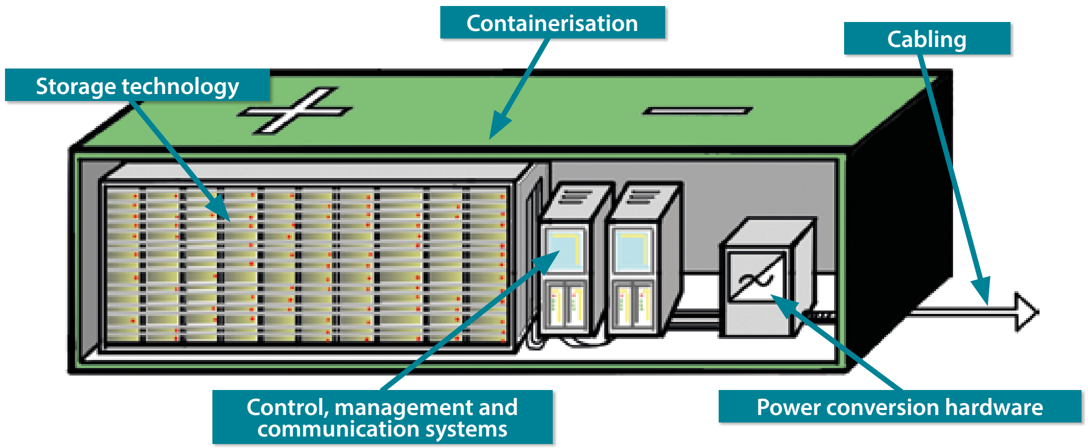
Storage technology	Potential	Rationale
Pumped hydro	Low	Proven technology already widely deployed, no major technological improvements are expected. There is potential for smaller scale pumped hydro systems to become viable, but this would be in bespoke locations and costs are unlikely to be lower.
Solid state batteries	High	Substantial reductions are predicted as a result of higher energy densities and economies of scale as global output of battery cells increases dramatically, primarily due to the transition to electric vehicles.
Flow state batteries	High	Substantial increased calendar lives and operating ranges are critical in the expected reduction costs. Automation is also expected to lower production costs.
Flywheels	Medium	Improvements in energy density, partly due to new construction materials, round-trip efficiencies and calendar life are expected to reduce costs.
CAES	Medium	Improvements in round-trip efficiencies are expected by storing thermal energy and limited economies of scale relating to plant equipment resulting in minor reductions in installation costs.
LAES / cryogenic storage	Medium	Cost reductions will largely be achieved through increasing the number and scale of individual facilities. A key aspect in increasing the number of projects is the fact that LAES facilities are not geographically constrained.
Supercapacitors	High	Given the increased demand for sub-second response and balancing in a more flexible energy system and co-located with other energy storage technologies, supercapacitors are likely to be subject to significant manufacturing cost reductions as a result of economies of scale.
Hydrogen	Medium	Increasing efficiencies will drive down costs. The total cost reduction potential is highly dependent on the hydrogen economy, as numerous types of hydrogen storage technology could be further deployed.

Storage systems – component costs and economies of scale

The cost of an energy storage project includes the core storage technology and ancillary costs including power conversion hardware, connection infrastructure, cabling, containerisation and potentially sophisticated management and control systems.

The balance of these different costs will depend on the scale of power (MW) and storage capacity (MWh) required for the services the storage project is designed to provide. Ancillary costs are relatively fixed, encouraging larger scale projects to maximise economies of scale.

The scale of research and development into storage capacity means this can be expected to continue to fall in price. However, ancillary costs may have less potential for cost reduction. This dynamic means that longer duration storage projects can be expected to see a more rapid fall in costs per MWh. Storage could, therefore become more cost efficient in future, where a longer duration service is required.



Economies of Scale

	Power output i.e. 10 MW	1 hr discharge i.e. 10 MWh	2hr discharge i.e. 20 MWh	3hr discharge i.e. 30 MWh
Site and infrastructure costs MEICA and civils containerisation	Power capacity (MW) costs Grid connection Power conversion	Storage capacity (MWh) costs (1) Storage units Control systems	Storage capacity (MWh) costs (2) Additional storage units Extend control systems	Storage capacity (MWh) costs (3) Additional storage units Extend control systems

Response service system (i.e. 10 MW/10 MWh)
Lower capital cost system if targeting high value, rapid response services, based on the delivery of power / MW (e.g. EFR)

Price/time shift and reserve service system (i.e.10 MW/30 MWh)
Higher capital cost overall, but lower cost per MWh if targeting reserve and price/time shift revenue streams

Controlling storage projects – enabling and supporting technologies

Technologies continue to develop that will enable storage assets to optimise their operation, maximise revenue, or potentially provide innovative services to access new markets. The way a storage asset is controlled, combined with the automation, sophistication and flexibility of these control systems, will be critical to ensure a storage asset achieves its full business case.

The primary revenue streams for storage assets are dependent on the ability to respond to signals such as:

- **Contractual notifications** (network event alerts, calls to generate)
- **Price thresholds** (wholesale price movements or peak charges/penalties)
- **Operational events** (demand profile peaks/troughs, loss of mains supply).

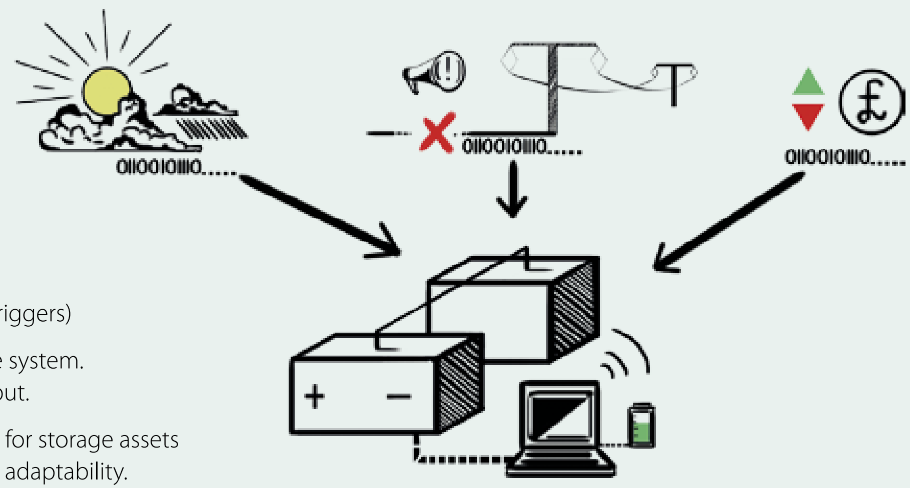
Forecasting these triggers and translating them to rapid, automated response is a potentially complex issue for storage operators. Storage control systems take into account a number of external data feeds[22] to enable this type of operation including:

- **Price data** (wholesale energy market spot price/day-ahead)
- **Weather data** (linking to solar/wind generation and demand conditions)
- **Network event data** (e.g. Capacity Market notifications, system stress event, system frequency triggers)

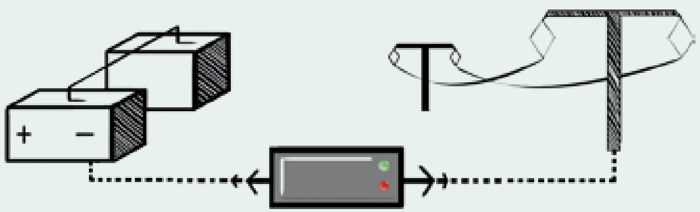
More inward-looking control systems will also be needed to maintain the performance of a storage system. Information, such as asset status (i.e. charge level) and temperature, will be key to maintaining output.

As the energy system continues to evolve and the markets for flexibility services change, the ability for storage assets to adapt their operation is key. The sophistication of control systems will be central to enabling this adaptability.

Data feeds and control systems



Smart network interfacing devices



Understanding how storage can provide value to the energy system drives the need for intelligent interactions between generation, storage and demand, at both network level and on an individual site basis. This has given rise to the development of smart network interfacing devices[23], utilising data analytics to better understand and manage the flow of energy between assets, sites, substations and the wider networks. These devices can perform a number of functions:

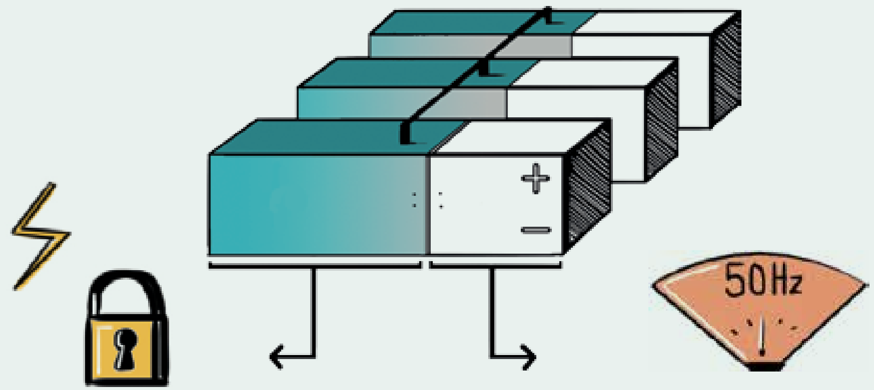
- **An approved method to operate generation assets that are under constrained grid export**
- **Flexible network operation, (i.e. Active Network Management)**
- **Monitoring the interaction of generation and demand directly connected behind the meter.**

There is potential for these type of devices and associated analytics to enable storage to interact with the network directly, as well as acting as a central hub to manage interactions between storage, generation and demand.

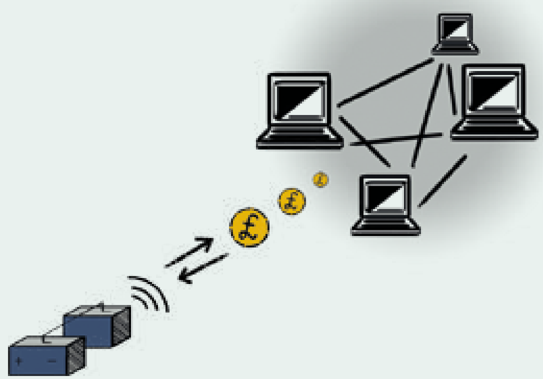
Operating modes and partitioning

Storage assets will often be pursuing more than one revenue stream to secure a viable return on investment. To achieve this, they will need the ability to switch the operating regime of storage to target a more lucrative revenue stream. For example, a storage asset could need to switch from standby under a frequency response contract, to charge up to full ahead of a potential Triad peak period.

An alternative to switching mode of operation, is the concept of partitioning, where a proportion of a storage asset's capacity is ringfenced or partitioned to perform a specific task and the remaining capacity is focussed on delivering a different service or function. For example, a storage asset deployed at a high energy using site could have capacity reserved to act as a back-up supply to parts of a site (similar to the operation of a UPS) whilst the rest of the storage capacity is allocated to provide peak charge avoidance. This approach to optimise benefits, may need the storage asset to operate concurrently, which could be an area that storage operators look to develop, as the needs of their systems becomes more diverse.



Blockchain



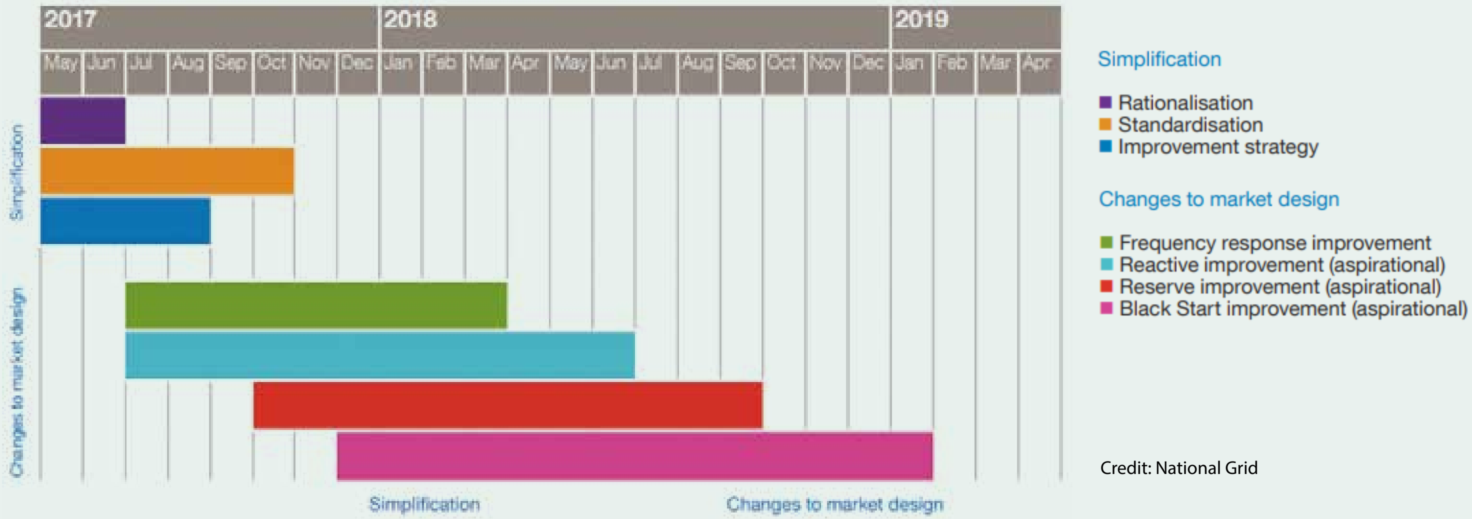
Storage systems are likely to earn revenues from providing a range of services to the energy market. The current highly regulated system can create barriers and make the route to market for these services convoluted and expensive. Reductions in energy market transaction costs would increase the value of the services that storage can provide.

An emerging technology for simplifying energy market transactions is using blockchain, a public digital ledger of transactions. Companies like Electron and Origami are aiming to use blockchain's guarantees of a secure, robust and transparent platform to underpin energy market transactions.

Flexibility procurement – new market opportunities

National Grid System Operator – meeting the needs of the system

Over the summer National Grid System Operator (SO) published the Future of Balancing Services24 and Systems Needs and Product Strategy (SNAPS). These documents gave a strong indication that a comprehensive portfolio of flexibility services are going to become more important than ever in order to balance the needs of the UK energy system. Within these documents were plans to not only "deliver a more cost-effective energy system by 2021", but also plans to simplify and overhaul the suite of balancing programmes currently procured by the SO.



Credit: National Grid

In the SNAPS the SO has set out a strategy and timetable to rationalise, standardise and simplifying the balancing services they procure. The response, reserve and reactive power services are all set to evolve, providing more clarity for storage investors in the revenue streams they can target.

One area the SO recognises improvement is needed in is the current frequency management services, (Firm Frequency Response (FFR/FFR-Bridging), Enhanced Frequency Response (EFR) and Frequency Control by Demand Management (FCDM)). These are key markets for storage, but have proved challenging with a low success rate for bidders. The SO is proposing to replace these with a service that can be either procured close to real time, or ahead of real time and adjusted to meet the immediate needs of the system.

The SO balancing services market has been critical for the current 'first wave' of battery storage projects. There is however a note of caution for new entrants, these markets will be finite in size, are likely to remain complicated to enter, come with notable penalties for underperformance and will be hugely competitive. Competition will come from other storage providers, potentially from new technologies and also from incumbents who have traditionally provided these services and are likely now to respond reducing their costs and improving their level of service.

The transition to Distribution System Operator (DSO) – procuring flexibility locally

The transition of DNO to DSO opens new potential markets and opportunities for energy storage. In simple terms DNOs are being asked to move from a passive role to a much more active role in managing the electricity network they operate. To avoid expensive conventional reinforcement DSOs are now looking for distributed energy resources to provide flexibility services at a local level.

Significantly, Ofgem want to ensure competition in the energy storage market and have confirmed they will stop DSOs operating energy storage in most cases – although some doors are left open.

This ruling from Ofgem means that DSOs will need to procure localised flexibility services and we have started to see a first glimpse of what this might look like with at least three examples in development:

SSEN **Constraint Managed Zones (CMZ) in Yeovil and Standlake**[25]

WPD **Flexible Power trial (part of Project ENTIRE)**[26]

UKPN **Expression of Interest (EOI) for flexible capacity**[27]

The UKPN EOI marks the first time a DSO has gone to the market for this type of flexibility service outside a trial or demonstration project. The results will give insight into who and what can deliver the required flexible capacity at the given availability times, voltage level and locations, at a practical price.

One point emerging from these early examples is that DSO flexibility calls are likely to be highly location specific, addressing local network issues. Given this, energy storage projects seeking to service this market will need to be in the right place.

Electricity network innovation strategy

Following an Ofgem intervention, DNOs were asked to prepare innovation strategies. After securing feedback from DNOs, this has been combined into an industry wide electricity network innovation strategy, managed by the Energy Networks Association (ENA). The main purpose of this strategy is to identify those challenges in the electricity networks that have been met by previous innovation projects and those that haven't.

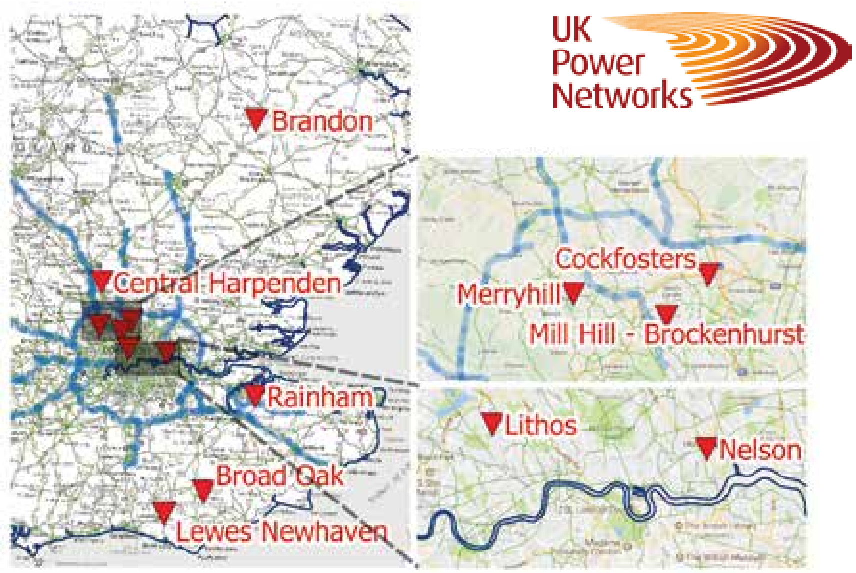
The Open Networks Project

Managed by the ENA in partnership with DNOs, regulators, NGOs and others, the Open Networks Project[28] has been described as a "key initiative to drive progress and develop proposals" by Ofgem and BEIS in their recent Smart Systems and Flexibility plan and it will be the main forum for driving forward the transformation in our energy networks.

The project will seek to:

- progress the transition of DNOs to DSOs,
- provide clarity and improve the interface between the transmission and distribution networks as these roles change,
- improve the customer's experience of their interaction with the networks,
- consider the charging requirements of enduring electricity transmission and distribution systems.

Locations with a potential need for flexibility identified by UK Power Networks



DNO	The DSO strategies – emerging principles	
Electricity North West – Bringing energy to your door	• Network capacity provision • Network capacity market management • Network access management and forecasting	• Service definition and charging • Wider market engagement
Northern Powergrid	• Delivering further innovation projects to understand the transition to a flexible system • Seek more opportunities to buy and sell storage and DSR • Deploy further Active Network Management areas	
SP Energy Networks	• Rollout and extend the use of active network management as a solution to manage network constraints • Introduction of Active Network Management working group to accelerate into Business as Usual • Network DSO classification to priority areas which are likely to benefit from a DSO model • Expand network monitoring to future proof legacy assets	• Modelling and investigation into ancillary services market and identifying cost effective solutions • Commercial arrangements in place with National Grid and DER providers within DSO trial areas • Development of DSO development strategy for network areas with limited network service provisions
Scottish & Southern Electricity Networks	• Greater choice and opportunity for customers, whilst ensuring the service we provide remains reliable, efficient and resilient, particularly for vulnerable customers • Integrating learning from innovation projects	• Cost efficient delivery of DSO model • Neutral facilitation of local and national markets to unlock local solutions by identifying and providing the visibility necessary to allow markets to function and trade energy throughout our network
UK Power Networks	• Facilitate cheaper and quicker connections using proven innovation • Use customer flexibility as an alternative to network upgrades • Develop enhanced System Operator capabilities	• Collaborate with industry to enable GB wide benefits • Prepare and facilitate the uptake of EVs
Western Power Distribution – Serving the Midlands, South West and Wales	• Level playing field access for all customers • Maximisation of accessibility to services for vulnerable customers • Efficient and economic whole system outcomes • Facilitation of neutral markets • Provision of services where no market actor exists	• Using flexibility services to deliver quicker, more efficient and cheaper connections • Deliver maximum value to individual customers offering network-provided flexibility services and all customers through optimised use of smart grid flexibility • Environmental benefits through minimisation of losses

Key themes

Enabling cheaper, quicker connections

Level playing field for customers and neutral markets

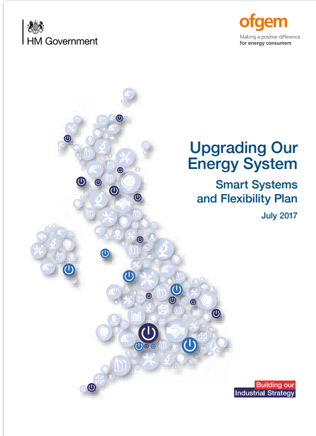
Increase use of Active Network Management

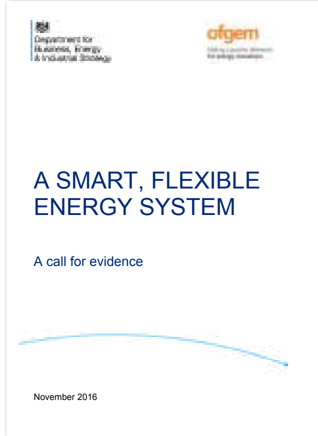
Enable local flexibility services

Energy storage in a smart and flexible energy system

The government has identified energy storage as a key component of its industrial strategy. BEIS and Ofgem's publication of a smart systems and flexibility plan[3] builds on this with a programme of actions to support the development of energy storage, including:

- to define storage as a distinct subset of generation, (with a proposal to amend The Electricity Act 1989 accordingly)
- changes to network charging regimes that adversely affect energy storage
- considerations around how co-located storage may affect generation that is accredited under subsidy programmes such as the FIT or RO
- clear signals from Ofgem around the prevention of DNOs owning energy storage, from the perspective of open and competitive markets
- pressure on the DNOs to enable quicker, cheaper connections for energy storage





The inclusion of storage as a key part of the UK's industrial and energy strategy has been very positive. However, there have also been announcements that have a negative impact on storage business models. Looking just at the numbers, our modelling shows the overall effect of regulatory changes is that many storage projects are less attractive than when we wrote our first paper on the topic last year. The loss of embedded benefits, changes to charges on the distribution network and proposed derating of storage in the CM outweigh the benefits of removing double charging.

Defining storage

Both BEIS and Ofgem have indicated the definition proposed by the Electricity Storage Network[29] is to be referenced as the basis of defining storage as a subset of generation. This is important from both the perspective of how storage is to be charged to use the network and what benefits it is (or is not) eligible to receive. In adopting this definition, questions remain[32] around the specific licence obligations and various grid codes* that storage is subject to, as well as whether storage is to be classified as intermittent or non-intermittent generation, which could further affect operating regimes and revenue streams.

** Connection and Use of System Code (CUSC), Balancing and Settlement Code (BSC), Distribution Code and Grid Code*

"The deployment of sustainable energy storage solutions is one of the key pillars that is required to achieve an energy system that is 100 per cent sustainable - a low carbon, resilient and balanced energy system. It is essential that financial institutions work closely with developers, regulators and policy makers to create a conduit for energy storage technology that will support the wider deployment of renewable energy generation. As this report identifies, some very helpful progress has been made on the regulatory side these past few months but more work is required to establish a stable, medium to long term regulatory framework that will help make this a truly 'bankable' asset class."

Phil Bazin, Environment Team Manager, Triodos Bank

Policy and regulatory developments around energy storage – mixed messages

Policy and regulatory development	When	Potential impact on energy storage
'Minded to decision' of removal of embedded benefits/Triad credits for embedded generators	Mar-17	**Negative** – the removal of Triad 'credits' to distributed generation removes a significant incentive. Storage could have enabled intermittent generation to focus the supply of their energy to the network during Triad times, thus securing firm financial benefit.
Removal of 'double charging' for storage, treating storage, for the purposes of network charges, as purely generation asset class	Mar-17	**Positive** – treating energy as a generation asset only for network means storage assets won't be charged to both 'fill' and 'empty'. However, the charges proposed to be removed are during times when storage is much more likely to be discharging, so the benefit is limited.
Ofgem Targeted Charging Review and Charging Futures Forum	May / Aug 2017	**Positive** – a holistic charging review is a positive outlook for the industry, with the potential to introduce a more up to date charging arrangement, that reflects the nature of a DG dominated network.
Launch of smart systems and flexibility plan	Jul-17	**Positive** – strong messages from government and the regulator that flexibility is a key component of the UK energy system – storage specifically mentioned as a key enabling technology.
Consultation around the de-rating of storage within the Capacity Market	Jul-17	**Negative** – the proposal to de-rate the capacity of storage in the Capacity Market, on the basis of storage being only able to supply its capacity for a short period of time, will impact significantly on business cases. The timing of the proposal after the auction guidelines were published is of particular concern to investors.
Reduction of distribution use of system (DUoS) 'Red Band' charges	Apr-18	**Negative** – the flattening of the evening peak delivery charge for large energy users is a blow to business cases for behind the meter storage projects. The Targeted Charging Review could mean that delivery charges are set to change even further.
Ofgem decision around RO accreditation for three 5 MW solar PV farms retrofitting co-located storage	Sep-17	**Positive** – permitting ROCs to be claimed for generation that has been diverted into storage is a gateway decision that will drive RO accredited generators to consider installing co-located storage more readily.
HMRC confirm 5 per cent VAT for solar and storage installed together	Sep-17	**Positive** – a small financial benefit, but one that was welcomed by the solar industry and storage sector.

Wider policy factors that may affect energy storage

Policy and regulatory development	When	Potential impact on energy storage
Elective half-hourly settlement for domestic and small commercial, allowing TouTs	June 2017	**Positive** – the introduction of elective half-hourly settlement (June 2017) paves the way for more variable TouTs, improving the benefits of energy storage for the small commercial and domestic markets. To grow the market further half-hourly settlement needs to become mandatory.
Government announcement around ending petrol/diesel vehicle sales by 2040, increasing the momentum for EV rollout	August 2017	**Positive** – the growth of the EV market has been the kick-starter for the wider energy storage sector. Further growth in the rollout of EVs could drive storage technology costs down and increase the level of charging infrastructure (and capacity to enable its deployment) across the UK.
Brexit	Ongoing	**Unknown**

Innovation funding for storage

A number of funding sources exist that could further the research and development of energy storage technologies. UK funding sources managed by BEIS, Innovate UK, Ofgem and the Advanced Propulsion Centre totalling in the region of £175 million and wider European funding sources (such as INTERREG, Horizon 2020 and the European Investment Bank) could unlock funding into the billions of Euros. This level of funding presents a significant opportunity for manufacturers and developers to improve the performance of storage technology, reduce costs and test the commercial viability of storage business models.

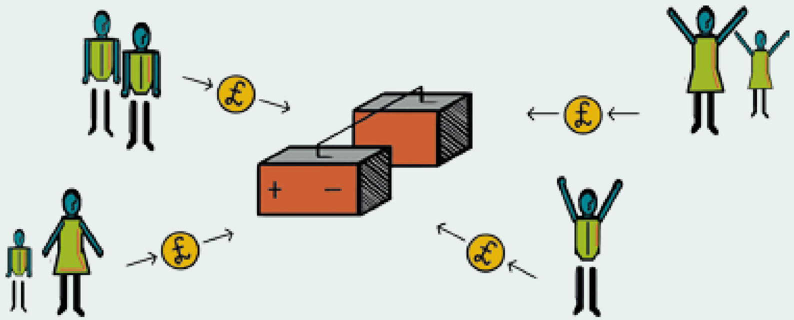
The Faraday Challenge

Part of BEIS' Industrial Strategy Challenge Fund, the Faraday Challenge[30] was launched in July 2017. Announced as a £246 million of government investment into battery storage and EV innovation. With a goal to ensure that "the UK builds on its strengths and leads the world in the design, development and manufacture of electric batteries." There are three funding streams available: **research**, **innovation** and **scale-up**.

While the first phase of funding applications is now closed, the second phase will aim to build on the most promising research and phase three will look to scale up the technologies at a new National Battery Manufacturing Development facility.

Crowdfunding

With the limited funding opportunities available, some storage innovators have turned to crowdfunding to finance their projects, to varying degrees of success. The crowdfunding model has to date largely be adopted by companies working in the domestic storage market, for example Powervault,[31] who produce domestic scale batteries, have raised over £4 million in funding over four funding rounds in the last three years. Whilst this type of funding model is proven in the domestic energy storage and EV innovation markets, the potential for this model to be adopted by utility scale storage companies remains to be seen.



Innovation funding sources currently open for applications

Name	Funding source	Application dates	Description	Amount available
EUREKA Eurostars	Innovate UK	Two calls for proposals each year 2014 to 2020	Funding exclusively for innovative and research-intensive SMEs that wish to partake in collaborative research and develop new products, processes or services. Applications can be with two or more participants from two or more Eurostars countries.	Up to 60 per cent of eligible project costs are accounted for. A maximum of €360,000 is available per UK project partner.
INTERREG V	European Commission	2014 to 2020	Part of the European Regional Development Fund, with a specific focus on sustainable development, INTERREG supports interregional cooperation projects. Projects involve policy organisations from at least three different countries in Europe and collaborate for three to five years.	Average total budget per project is €1 million to €2 million. Overall budget is €10.1 billion.
Horizon 2020	European Commission	2014 to 2020	Funding for projects that explore the feasibility of new knowledge or technology in specific research areas: • Reducing energy consumption and carbon footprint • Low cost, low carbon electricity supply • Alternative fuels and mobile energy sources • A single, smart, European electricity grid • New knowledge and technologies • Robust decision making and public engagement • Market uptake of energy and IT innovation	€5.931 billion available towards energy projects
Electricity Network Innovation Competition	Ofgem	Annual funding opportunities	Aimed at electricity network companies to develop and demonstrate innovative technologies, operating and commercial agreements. Projects will aid all network operators in understanding future environmental benefits, cost reductions and security of supply in the transition to a low carbon economy.	Up to £70 million per year
Innovate UK Innovation Competitions	BEIS/Innovate UK	Ongoing competitions	Currently open competitions include "accelerating the transition to zero emissions vehicles (research and development)" and "emerging and enabling round 3".	
European Investment Bank Research and Innovation Project Loans	European Investment Bank	Ongoing	Loans available to finance investments in research and innovation carried out by private and public sector companies or entities located in the EU. Includes research and innovation into renewable generation, infrastructure and new technologies.	Lending in renewables was €6.2 billion per year in 2010.

The next wave of storage projects

The first wave of storage projects was focussed on high value response service contracts and the Capacity Market. As these projects move from development to financial close and deployment, Regen's analysis indicates that future waves of deployment will target storage co-located with generation, commercial and industrial applications behind the meter and domestic or smaller scale storage. Though some projects from future waves are beginning to emerge, the operational and financial benefit of co-locating storage with both generation and demand suggests these business models will be driving the post-EFR projects – the next wave.

Wave 1
(Now-2020)

Response services driven by EFR and FFR markets

First behind the meter projects are installed

First co-location projects installed

Household/domestic "early adopters"

Wave 2
(Early 2020s)

Generation co-location and behind the meter models become viable

Market for commercial and industrial users/generators grows rapidly

Co-location projects with solar PV and wind become economically viable

Domestic and community storage market expands

Wave 3
(Mid/late 2020s)

Expanded market as new business models are developed

Aggregation and new trading platforms

Local supply and virtual markets

Generation and storage co-location now becomes standard

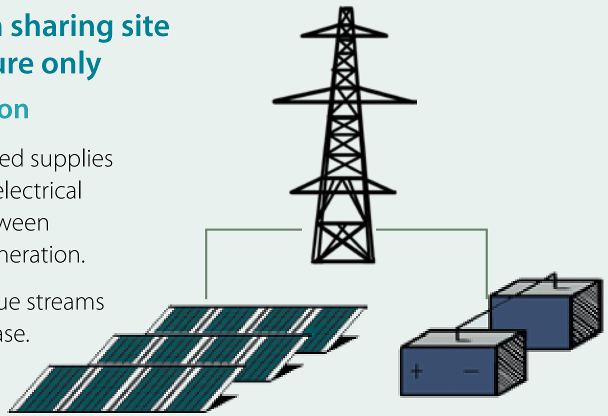
Heat and electricity storage

Co-location sharing site infrastructure only

Cost reduction

Separate metered supplies and MPAN, no electrical interaction between storage and generation.

Separate revenue streams and business case.

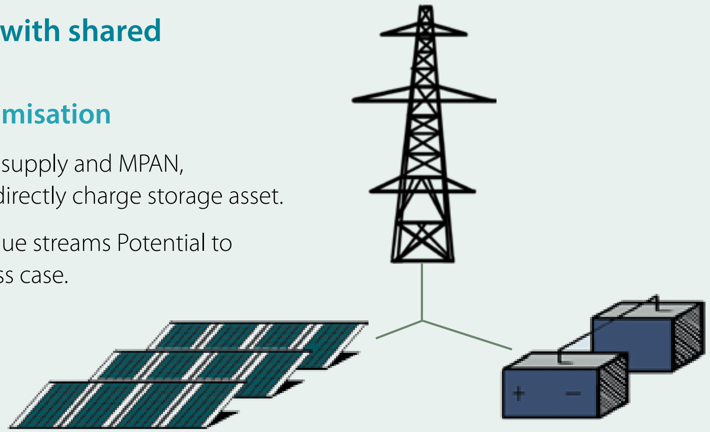


Co-location with shared connection

Revenue optimisation

Shared metered supply and MPAN, generation can directly charge storage asset.

Optimised revenue streams Potential to enhance business case.



Building the business case for co-located storage

Co-locating energy storage with variable renewable generation, or alongside sources of demand, is an obvious use for a flexible storage asset. Store energy when it is cheap – when the sun is shining and the wind blowing – and use that energy when demand and costs are high.

In practice, it is currently difficult to make a pure price arbitrage model viable without access to additional higher value revenue streams. Hence the current focus on auxiliary service market such as frequency response. In part, the challenge is that storage capital costs are still high compared to the arbitrage value that might be obtained. Other challenges include the complexity of site optimisation and the regulatory and legal complexity that co-location projects face.

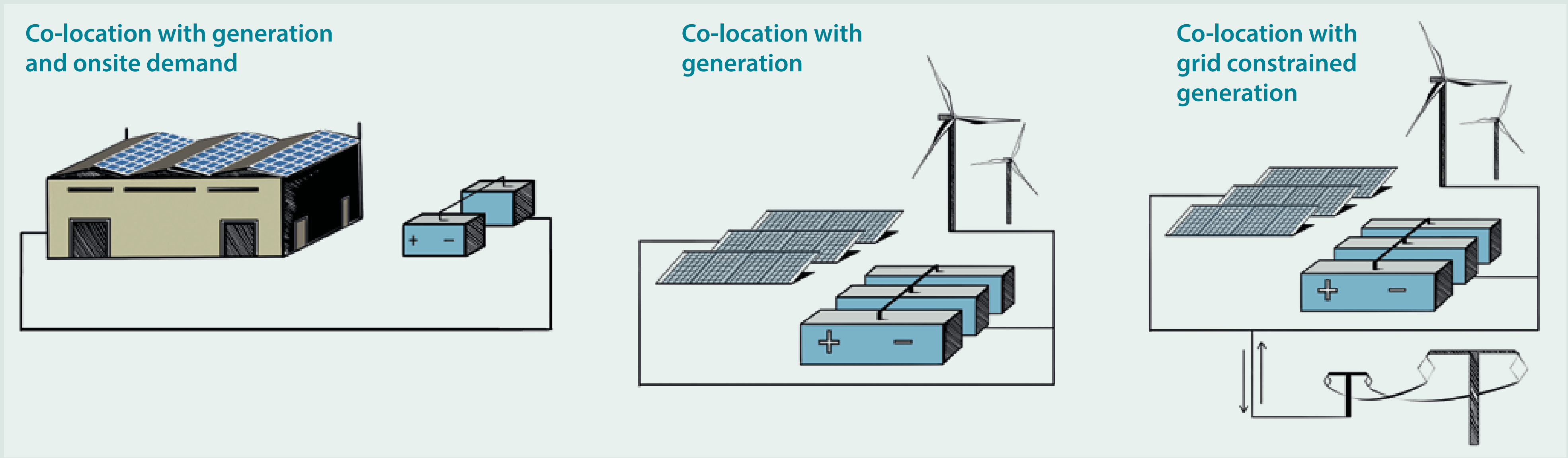
The market is evolving however and several developers that are now looking seriously at co-location projects, not just in the sense of sharing site infrastructure and a grid connection, but also optimising site assets to maximise value.

In the future storage could be co-developed with every wind and solar farm, every tidal project. The question is in what form, and how quickly, genuine co-location business models will develop.

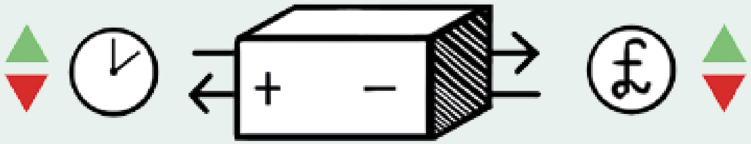
As an exercise in forward thinking Regen has looked in some detail at co-location models to better understand the optimal scale of assets, the relevant importance of each revenue stream and to assess how far they are from commercial viability.

To explore this we have modelled three generic types of co-location models:

- **Co-location with generation**
- **Co-location with grid constrained co-location**
- **Co-location with generation and onsite demand**

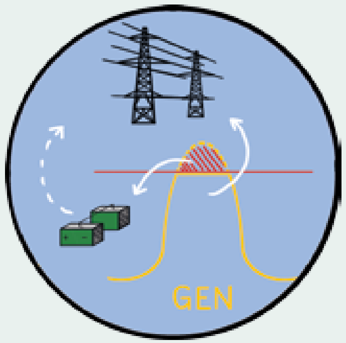


Key benefit streams for co-located storage



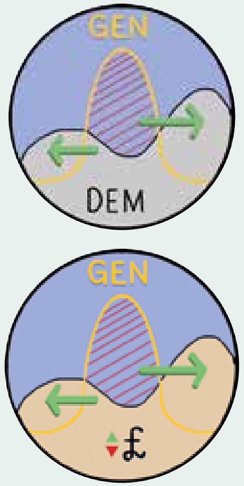
Electricity price arbitrage

The potential to utilise storage to optimise when a generator exports and sells their energy to the market is potentially a key benefit of co-operating storage with generation. Control systems that manage the flow of energy between generation, storage and the network, driven by price data, forecasts and other data feeds. The volatility and spread of wholesale electricity prices will determine the level of financial benefit from price arbitrage.
A consideration here is that as more assets gain benefit from price arbitrage they reduce the inherent price volatility in that market.



Bypassing export constraints

Generation projects that are under export limitation (or an equivalent flexible connection agreement) could 'unlock' the export limited output. This can be achieved by diverting a proportion of the peak generation into storage, until such time where the generation output is sufficiently below the export limit, for the storage asset to discharge. This can also conceptually enable the potential for 'oversiting', where a generation asset is installed at a higher capacity than the approved export capacity, but the storage acts as mitigation by ensuring the export limit is never reached. This arrangement would likely require engagement and approval from the DNO.



Maximising self-consumption of generation

Energy storage enables the 'point of supply' or 'point of use' of generated energy to be shifted in time.

For a behind the meter scenario, this functionality can be driven by the need to more closely align generation and demand, where onsite generation peaks may mismatch periods of high consumption.

This is achieved by diverting energy into storage, that would have otherwise been exported to the grid. Whilst relatively small conversion losses are inevitable, discharging/self-supplying this energy when generation is low (or demand is up), closely aligns the generation and usage profiles and resultantly reduces imported electricity for the site.

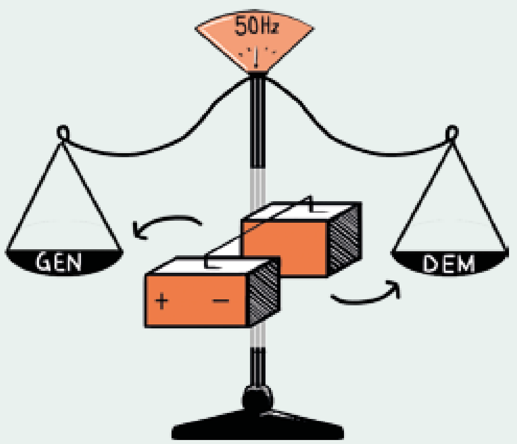
This function of storage works for sites with a number of supply arrangements (flat price tariff, day-night, or peak cost periods), though the value notably increases with more variable/exposed supply tariffs.

Avoiding peak network charges

For larger energy users that are subject to variable network charging (currently specifically transmission (Triad) and distribution (Duos) use of system residual charges), the potential to use storage to reduce a site's exposure to these periods could be valuable.

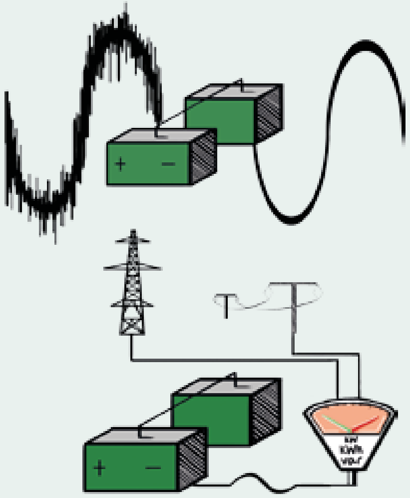
Either charging a storage asset from the grid or onsite generation and then self-supplying/ discharging during a peak cost period is a potentially viable alternative to traditional strategies such as running diesel generators or dropping operational consumption - potentially to the detriment of operational stability and/or productivity.

Additional benefit streams which could be 'stacked'



Response services

High value response services are the prime driver behind the first wave of storage projects. The rationalisation of National Grid's frequency response products and the rise of local flexibility services, could enable co-located assets to still bid into these high value programmes. The high level of competition and finite need of system operators, means that the likelihood of securing a response service contract is uncertain at best and should not be relied upon to secure a viable business case.

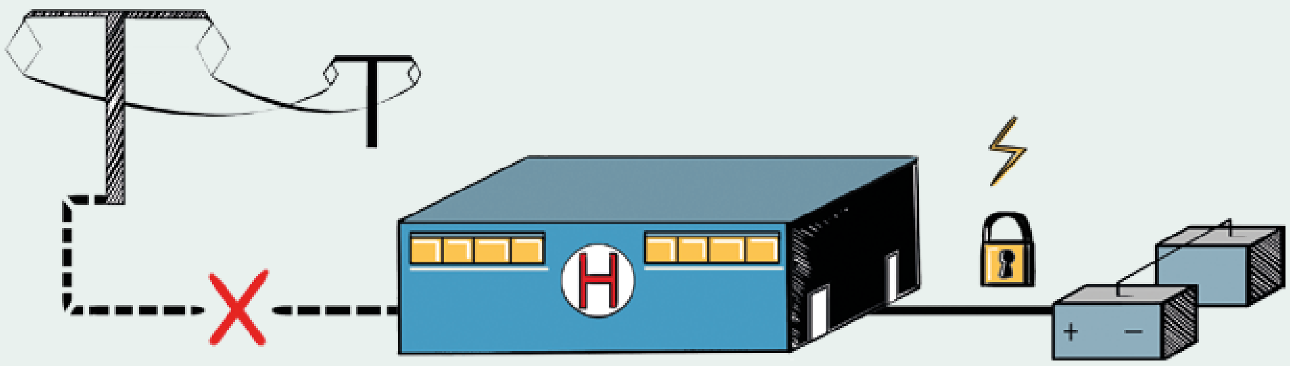


Power quality services

Linked to system frequency regulation, the ability to provide voltage support or reactive power services to the network, has traditionally been the role of generators (gas plants, flywheels and hydro turbines) or dedicated technologies such as Synchronous Compensators. The ability for batteries to supply reactive power sub-second provides a potential opportunity to dominate this market. However, the market for reactive power services is small and of relatively low benefit, so is not considered to bring significant value to co-location business models.

Mains backup provision

An additional service that energy storage can provide to an operational site is to act as a back-up supply. Uninterruptible Power Supply (UPS) technology has been around for many years, providing emergency backup power when mains power fails for a key assets or sensitive operational equipment on site. Larger scale storage devices co-located with high energy using sites could provide these services to cover a larger proportion of a site's loads, though the storage system's energy capacity (MWh) and operating arrangements will dictate how many hours of backup it can provide to a site, plus the additional capital for secondary inverters. The value of this type of UPS will vary significantly depending on the nature of the site and its sensitivity to even short term power interruptions.



As a general assessment, Regen's business case modelling shows that further storage cost reduction and/or additional revenue streams are required to enable co-location models to be viable*.

Nevertheless, the analysis did suggest two potential business models that are likely to become prevalent in the market in the short term:

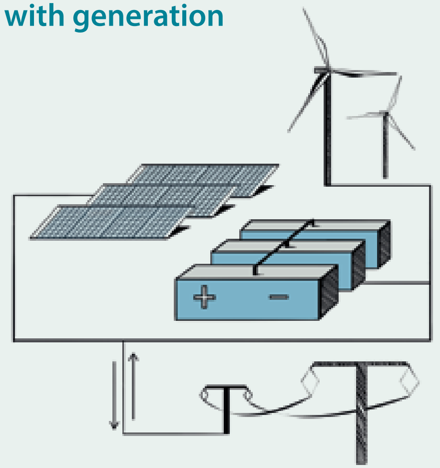
- **A behind the meter storage battery co-located with a high energy user, and sized to maximise the consumption of onsite generation, could become viable especially in areas of high peak distribution and network costs**
- **Co-location with generation, especially in a grid export constraint situation, could also become attractive provided arbitrage was against the wholesale price or system (imbalance) price**

As storage costs have fallen these business models are becoming more viable. There is still a gap however and a further 20-30 per cent capital cost reduction, which is certainly possible within a short time horizon, would transform the business case outcome.

A pure 'co-location' business case is currently difficult without access to additional revenue streams, (such as frequency response) and/or cost reduction. Price arbitrage requires access to markets with high price volatility.

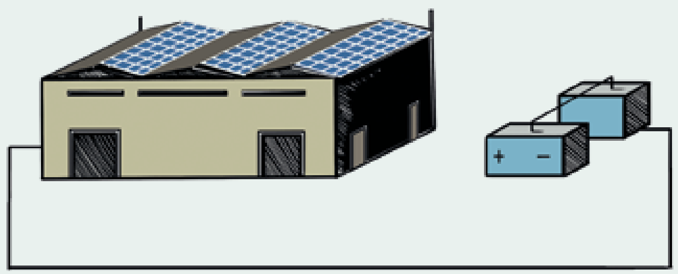
* Any assessment will be heavily dependent on individual site factors. Projects may be viable where there are specific cost and/or revenue factors.

Co-location with generation



- Sized to optimise price arbitrage and grid constraint management
- Definition of storage as generation important in relation to network costs
- Loss of embedded benefits for Triad avoidance has had a significant impact

Co-location with generation and onsite demand



- Behind the meter
- Sized to maximise self-consumption of onsite generation
- Time of use tariff enhances peak price avoidance
- Distribution and transmission cost avoidance (Duos and Triad charges)

Network and distributed benefits

The modelling highlighted the impact of recent changes in the way network charges and benefits are regulated.

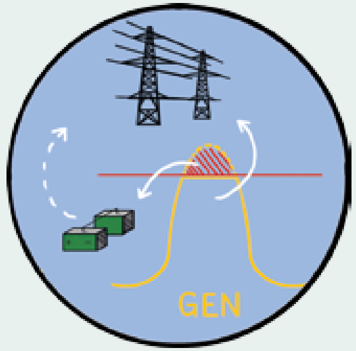
The exact impacts will depend on the licence area but, using the South West WPD area charges as an example, the business case was impacted by:

- **The loss of transmission embedded benefits (Triad) for distributed generators. Triad avoidance benefits remain, for the moment, for behind the meter assets that can reduce peak demand.**
- **The proposed definition of storage as a generation asset*, reduces the import costs for generators, but would not apply for projects whose primary function was to meet demand.**
- **Whether storage is defined by the DNO as an intermittent or non-intermittent generator has a significant impact on generator credits.**

* Ofgem's proposal, which is in consultation, is to define storage as a generation asset, for the purposes of applying final consumption levies, so long as its primary function is to export to the grid and not meet onsite demand.

Grid constraint management and over-siting

As expected the business case modelling highlighted the additional value that storage can offer a generator in a grid constraint environment or where the generator has elected to install additional capacity above the grid export limit, sometimes referred to as over-siting.

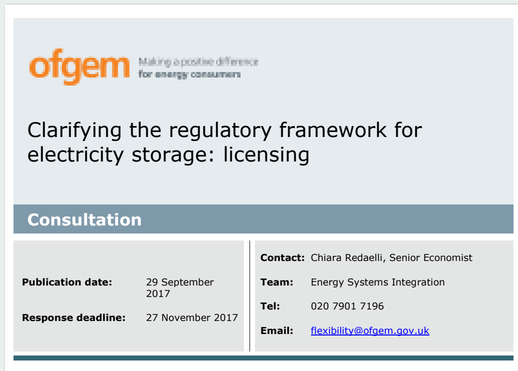


Should storage be defined as non-intermittent generation?

Ofgem is consulting[32] on a proposal to define storage as a generation asset for the purpose of applying network charges stating that:

"Storage can open up many possibilities. It can help to integrate variable renewable generation, reduce the costs of operating the system, and help avoid or defer costly reinforcements to the network. However, it needs a level playing field to compete."

Following this logic, it would make further sense to define storage as non-intermittent generation which would open the opportunity for storage to earn additional Distribution Use of System credits especially during red band periods.
At the moment, how storage will be treated by DNOs is not clear.


ofgem Making a positive difference for energy consumers

Clarifying the regulatory framework for electricity storage: licensing

Consultation

Publication date: 29 September 2017

Response deadline: 27 November 2017

Contact: Chiara Redaelli, Senior Economist

Team: Energy Systems Integration

Tel: 020 7901 7196

Email: flexibility@ofgem.gov.uk

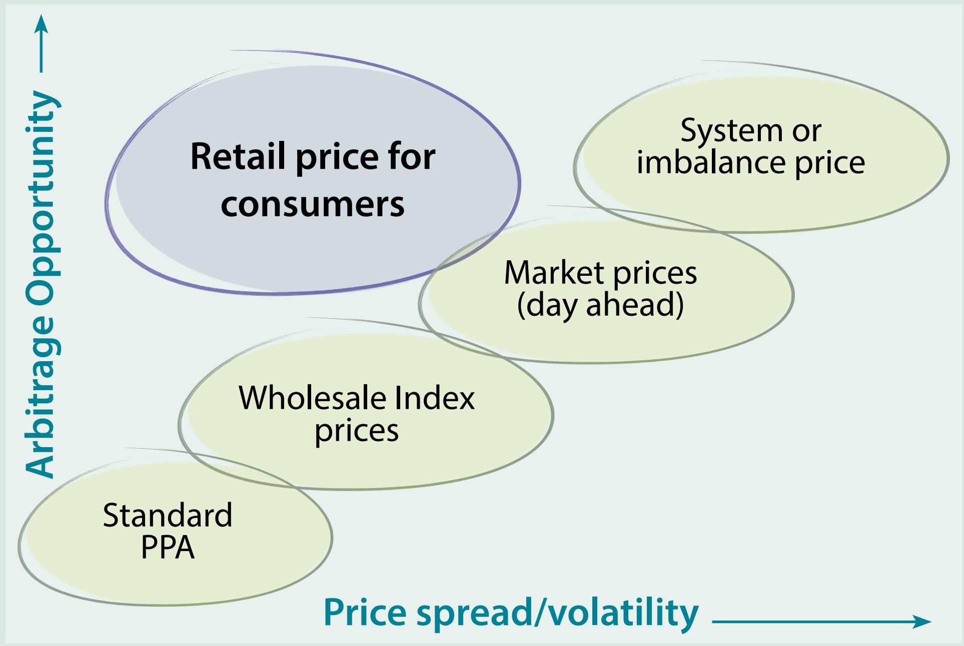
The value of price arbitrage

As the storage market develops the ability to capture value from price arbitrage is expected to become the most important source of revenue, and the main driver of storage growth.

Price volatility – the spread between low and peak price periods – is normally something that an energy generator, or an energy consumer, will seek to avoid. The introduction of a storage asset however, especially one that can respond almost instantaneously to price signals, opens up the possibility for generators, consumers and energy traders to take advantage of price differences.

Storage enabled arbitrage can take several forms, for example:

- **Enabling a demand consumer to take advantage of a time of use tariff to avoid peak retail and network prices**
- **Enabling a generator to store energy during high generation / low electricity price periods**
- **Enabling energy traders and suppliers to respond to market volatility and to better manage their trading position**



Getting closer to the market price

The more price volatility the greater the opportunity for storage enabled arbitrage. Regen's modelling shows that there are typically limited opportunities for generators to arbitrage against a standard Power Purchase Agreement (PPA), even one with a peak/off-peak price element. In response a number of energy supply companies are now looking at a storage based PPA which could offer more value in recognition of storage's greater flexibility.

A PPA linked to a wholesale index price offers more opportunity but the highest value (and risk) would be obtained if a storage asset is able to arbitrage directly against the market price or against system price (also referred to as the imbalance price).

Ownership, or co-ownership, of a storage asset by an organisation that already has a trading function, has an imbalance exposure risk in the balancing mechanism market, would therefore make a lot of sense. This is one reason why large energy supply companies such as Centrica, EDF and others have moved swiftly into the storage market.

For independent storage operators, that are not themselves energy traders, this raises a question of how to access the wholesale and balancing mechanism market. If market access is in partnership with an energy supplier (trader) or an aggregator, the form of contract, platform capability, value share and value commitment must be considered.

Opening the wholesale and balancing mechanism to independent aggregators would create a route to market for storage operators and this is one of several options being considered by Ofgem as an outcome from the Smart and Flexible Energy System Call for Evidence.

The role of the aggregator

The role of aggregators, and the opportunity for them to provide a variety of services to both energy generators and to energy consumers, has grown in recent years. Aggregation enables smaller scale generators, storage providers and consumers to provide flexibility and grid balancing services, and secure associated revenues, which they would otherwise be unable to do due to small scale and the complexity of contractual arrangements.

The National Grid website lists 19 companies providing commercial aggregation services[33]. These range from independent aggregators to larger energy supply companies that offer aggregation services. Aggregators currently provide a route to market for a number of ancillary services including:

- **Demand Side Response**
- **Short Term Operating Reserve (STOR)**
- **Capacity Market**
- **Frequency response**

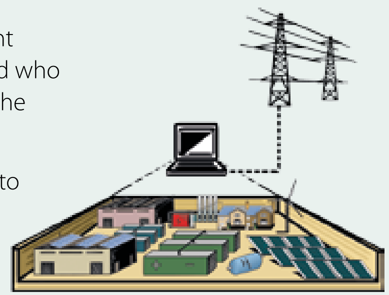
In addition, aggregators will offer customers with services to help them better manage and reduce energy costs including minimising transmission and distribution network charges. To do this, aggregators have the capability to:

- **Aggregation and co-ordination of a portfolio of generators and energy consumers**
- **Undertake the formal contractual arrangement with the flexibility service procurer**
- **Provision of aggregation software platform and control hardware that enables the control of the asset in order to respond to the given flexibility service call/event**

For a storage asset owner, an aggregator can provide access to new sources of value in the auxiliary services market, key considerations however include the form and term of the contract, value sharing and revenue certainty.

Ofgem considers increasing the role of independent aggregators and opening up the balancing market

Allowing aggregators to participate directly in the Balancing Mechanism market would open up a new high value market for energy storage. Independent aggregators are defined by Ofgem as "parties who bundle changes in consumer's loads or distributed generation output for sale in organised markets and who do not simultaneously supply the customer with energy. Independent aggregators currently have direct access to various ancillary services markets and the Capacity Market but not the Balancing Mechanism and the wholesale electricity market".[34]



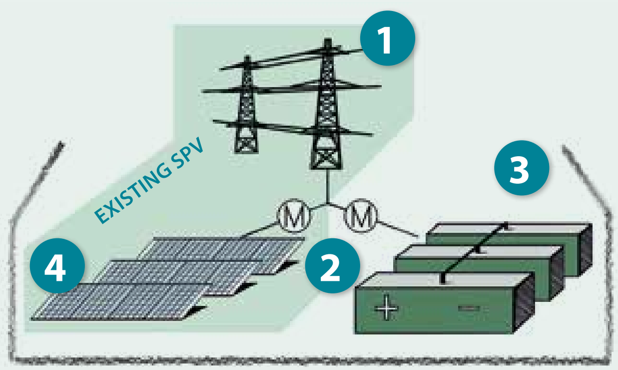
According to Ofgem, the responses to the Smart, Flexible Energy System Call for Evidence showed wide support for independent aggregators to be able to access directly electricity markets they cannot access now and that independent aggregators are delivering a significant share of flexibility services. To enhance market competition, Ofgem is now considering how the regulatory framework can be redesigned to give independent aggregators greater access to the market.[35] This could include access to the Balancing Mechanism and to register a Balancing Mechanism Unit (BMU), which would potentially open a new price arbitrage market for energy storage providers, and would have a radical impact on how the UK energy system is managed.

Emerging legal and commercial issues

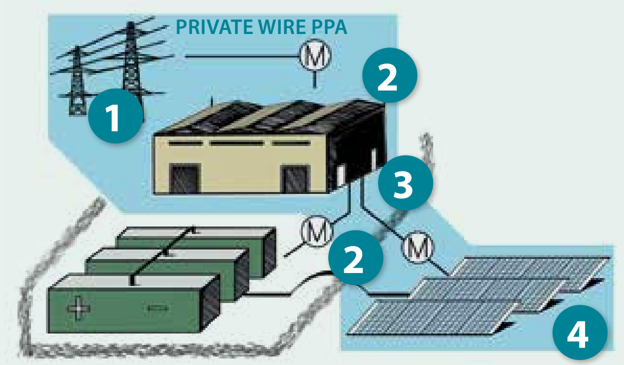
Our modelling is based on an assumption that the storage assets will be owned by a third party developer, most likely by way of special purchase vehicle (SPV) company created by the developer. The assumption in turn is that one or more legal agreements will need to be in put in place between the storage owner and either the existing generator SPV or the high energy user whose generation assets the storage will be interacting with. Amongst other issues, the relevant agreements may need to address include the basis on which the different parties will be allowed to make shared use of a single point of connection to the grid and, depending on the business model for the storage project, what commitment is being made by the generator SPV or high energy user to maintain a particular level of generation or electricity demand.

On any project where the existing generation assets are FIT or RO accredited or governed by existing PPA arrangements, it will also be vital that an appropriate metering solution has been devised to ensure that the introduction of storage will not jeopardise the relevant accreditation or cause the generation asset owner to be put in breach of its PPA terms.

Standalone generator SPV and storage



High energy user ◄ ► generator PPA and storage



Legal and commercial agreements – key considerations

(1) **Potential modification of existing grid connection agreements**

(2) **Additional import/export metering between assets and parties**

(3) **Adaptation or creation of new land lease agreements**

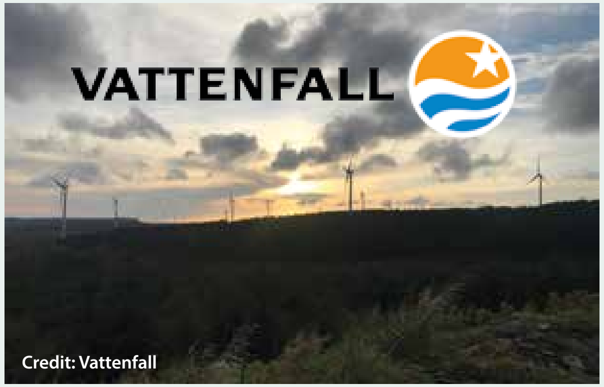
(4) **Ensuring retention of existing subsidy accreditations (FIT/ROC)**

"One of the major barriers to co-location projects to date has been the lack of specific guidance from Ofgem on how storage can operate alongside an existing FIT or RO accredited project. Whilst specific guidance is still awaited here, we do now at least have a high level indication from Ofgem that storage can in principle work along existing FIT or RO projects.

Beyond accreditation issues, on any co-location project, it will be necessary to review existing lease, PPA and grid connection arrangements to understand what variations, or new agreements, may be needed to allow for the introduction of storage.

In addition, where the storage will be separately owned, careful thought will need to be given to the dependency the storage owner will have on what the generation owner or high energy user does or does not do, including around use of any shared grid connection. A number of the issues commonly encountered on private wire PPA projects may apply equally to storage projects where the storage is co-located behind the meter."

Maria Connolly, Head of Real Estate, TLT LLP



Credit: Vattenfall

Pen y Cymoedd Wind Farm

Wind and battery storage co-location

Situated in South Wales, the 76-turbine Pen y Cymoedd wind farm reached its full generating capacity of 228 MW in spring 2017. Situated in South Wales, the 76 turbine Pen y Cymoedd wind farm reached its full generating capacity of 228 MW in spring 2017. Vattenfall have sought to utilise the onsite grid connection and are in the process of co-locating 15 MWh of BMW i3 Lithium-ion batteries. Vattenfall has sought to utilise the onsite grid connection and are in the process of co-locating 15 MWh of BMW i3 Lithium-ion batteries, Battery@PyC.

Operating independently from the wind farm, the storage system successfully secured an EFR contract and will be predominantly providing these frequency response services to the network.

"This is Vattenfall's biggest battery project to date and we think it is part of a smart transition to a fossil free Britain and Europe. We have ambitions for more batteries at our wind farm sites across Europe and so I hope that Battery@PyC will herald more storage facilities in the UK."

Gunnar Groebler, Head of Business Area Wind, Vattenfall

Credit: Camborne Energy Storage

Somerset Solar Farm

Solar PV and battery storage co-location

Camborne Energy Storage brought online a 250 kW/ 500 kWh storage system in late 2016. The first grid-scale Tesla Powerpack system in Europe, this Lithium-ion battery system is co-located with an existing solar farm in Somerset.

The storage asset takes in energy from the network at times of oversupply, looking to mitigate the need to curtail connected generation and provides energy back to the distribution network in times of high demand. The storage asset also targets Triad benefits during the winter and successfully contracted to provide FFR services, through aggregator Open Energi.

"It demonstrated the vital role of energy storage in delivering secure, low carbon power to the UK. We are aiming to co-locate further energy storage with renewable generation throughout the UK and help make our electricity system fit for the future."

Dan Taylor, MD, Camborne Energy Storage

Credit: Highview Power Storage

Pilsworth Power Plant

Liquid Air Energy Storage (LAES)

An LAES system located in Bury, Manchester has received £1.5 million of Innovate UK funding, to add supercapacitors and flywheels to their existing 5 MW/ 15 MWh pre-commercial demonstration plant. This project is a world leading example of the technology.

LAES works by liquifying gases at a very low temperature and then releasing the gas through a turbine. LAES can provide low cost, large scale, fast response (minutes), long duration (hours to weeks) energy storage using existing technology and integrating waste heat (or cooling) from other sources.

"A hybrid LAES system provides the powerful combination of instant start and long duration storage and is an important step for Highview as it broadens the range of services which LAES can supply and will help enhance the economic case for its adoption."

Gareth Brett, CEO, Highview Power

Credit: Anesco

Clayhill Solar Farm

Solar and battery storage co-location

Anesco have recently opened a 10 MW solar farm co-located with 6 MW of battery storage, with panels and the storage units provided by technology Chinese manufacturer BYD.

The inclusion of storage into the project was crucial to make the development feasible without subsidy support. Anesco state that another critical factor was the inclusion of 1.5 kV inverters, the first of their size to be installed in Europe.

"For the solar industry, Clayhill is a landmark development and paves the way for a sustainable future, where subsidies are no longer needed or relied upon.

Importantly, it proves that the government's decision to withdraw subsidies doesn't have to signal the end of solar as a commercially viable technology."

Steve Shine, Executive chairman, Anesco

Credit: redT Energy

The Olde House

Solar, flow battery and demand co-operation

RedT Energy Storage have recently installed a 90 kW, 1 MWh liquid energy storage system at The Olde House, a working farm in Cornwall. The storage system used Vanadium Redox Flow battery technology to store energy in liquid form.

The system is co-located with a 250 kW solar array currently in place and will time-shift the generation of this array for use in their onsite holiday properties.

A partnership with Centrica is helping to identify additional revenue streams for the project in the form of price arbitrage and frequency response to the grid, integrating with Centrica's local energy market trial.

"redT's machines will demonstrate how distributed energy grids such as this can embrace solar generation by coupling with energy storage to provide reliable, cheap energy all day and night, so called 'Firm Solar'."

Scott McGregor, CEO, redT Energy

Credit: Evo Energy

Telford Distribution Centre

Solar, storage and demand co-operation

In a significant collaboration between a number of companies, energy from the 3.8 MW rooftop solar array on Lyreco's Telford distribution centre will now be stored when necessary and provide services to the grid through an aggregator.

The 500 kW/950 kWh Tesla Powerpack battery storage unit, which was installed by EvoEnergy, will additionally provide energy directly to the distribution centre itself, improving self-consumption and avoiding high triad charges. The main financial beneficiary of the project is Sapphire Energy Ltd (a company backed by Guinness Asset Management EIS Investors), who are leasing the batteries to Lyreco over 15 years.

EvoEnergy will also be installing six electric vehicle charging points so that staff and visitors to the distribution centre may benefit from the solar and storage system.

Conclusion

Progress

Both government and the industry see energy storage as an important disruptive technology in a decentralised, flexible UK energy system. With 500 MW of storage capacity in the pipeline, the first wave of projects (driven by the EFR and CM) is a firm basis to build upon, enabling investors, developers, asset owners and system operators to better understand the costs and capabilities of storage assets.

The combination of government backing as a key part of the industrial strategy and cost reductions driven by high levels of investment is generating further investor interest and reinforcing existing and emerging business models. Storage has the potential to become a ubiquitous feature of the overall energy mix, providing flexibility and reducing costs.

Challenges

Looking beyond the inevitable hype in a rapidly developing technology there are significant challenges for the next wave of storage projects. Our modelling shows that further cost reduction is needed to enable co-location of storage with generation and demand to become a viable business model. One challenge is to develop longer duration storage assets with increased MWh capacity.

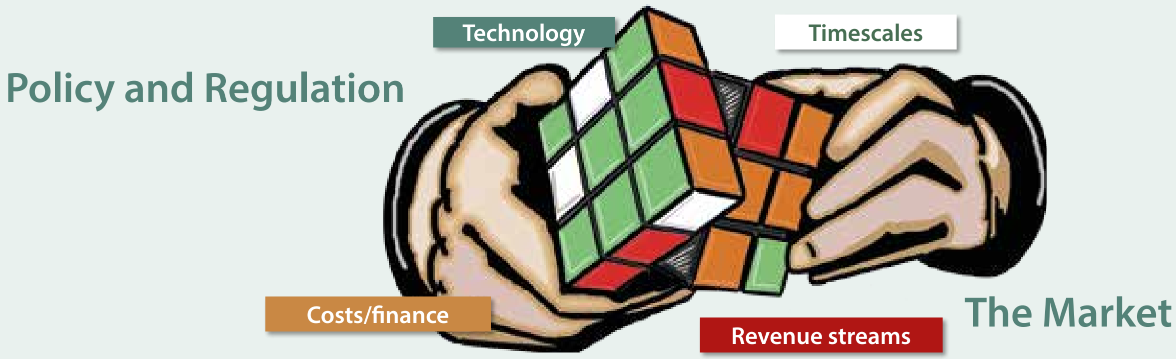
Government have conveyed some mixed messages for storage through recent policy changes. Strong strategic signals and innovation funding have been compromised by decisions that will negatively impact the business cases for many existing projects. The move to de-rate storage in the CM without proposing a way to value the flexibility and responsiveness of storage, is an example of an abrupt policy change that will have detrimental effects on storage investment and project bankability.

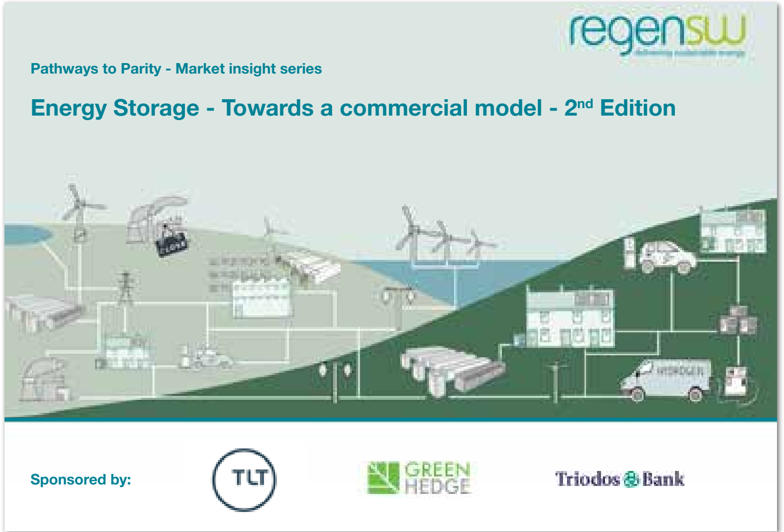
Key enablers

The combination of innovation funding and market growth can be expected to drive the cost reductions in storage that are required. The government and the regulator must also find ways to value the role, responsiveness and flexibility that storage can bring to the energy mix. BEIS and Ofgem's smart and flexible system plan is a good basis. However, further measures are needed including:

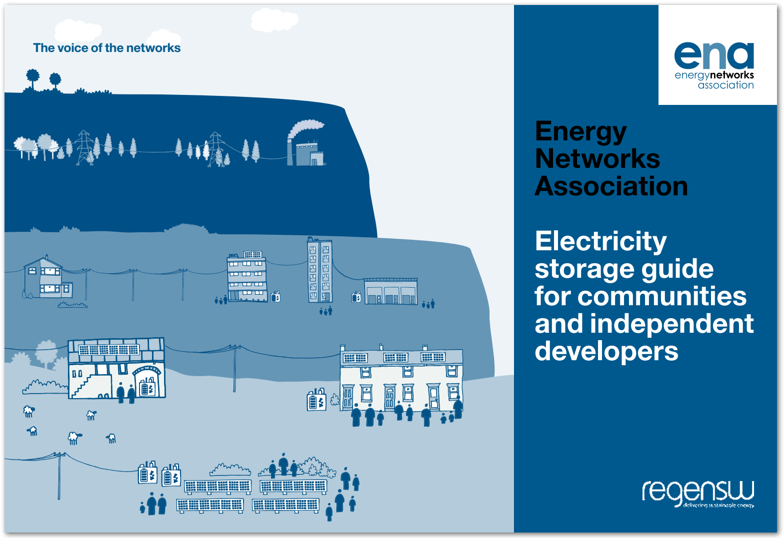
- **enabling more participants to access the Balancing Mechanism to use storage to arbitrage against the (often volatile) system imbalance price**
- **reform of network charging to better value local balancing of supply and demand**
- **the SO delivering on plans to rationalise and simplify national flexibility markets**
- **DSOs developing open local flexibility markets that smaller storage projects can access**

As technology improves and costs reduce, the 'hand of the market' and the 'hand of regulation' needs to be working together to enable energy storage to realise its full potential and deliver its true value to a decarbonised, decentralised and flexible energy system.



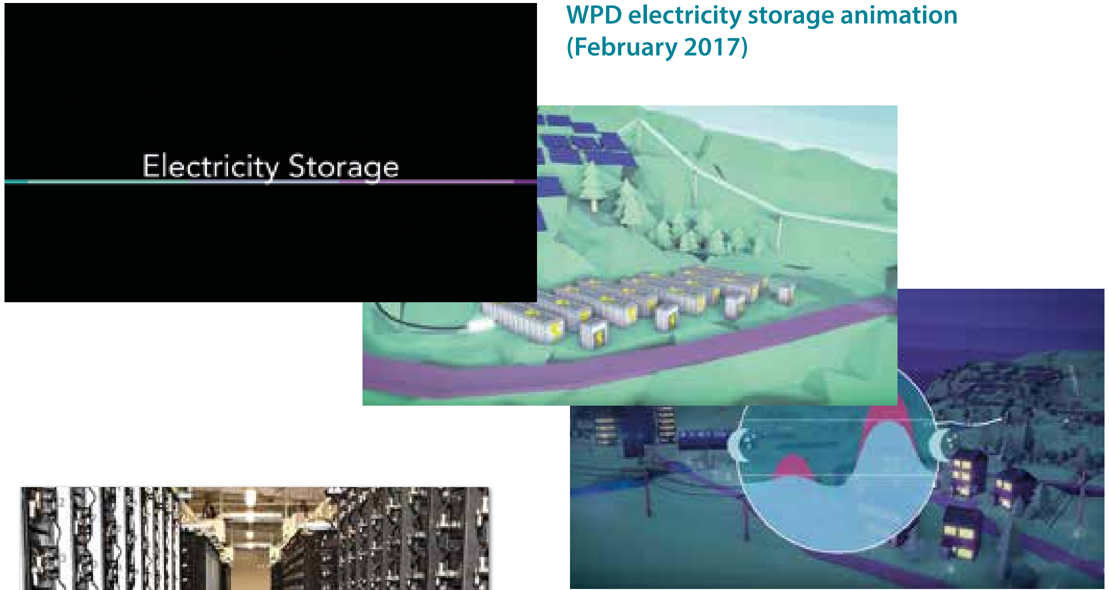


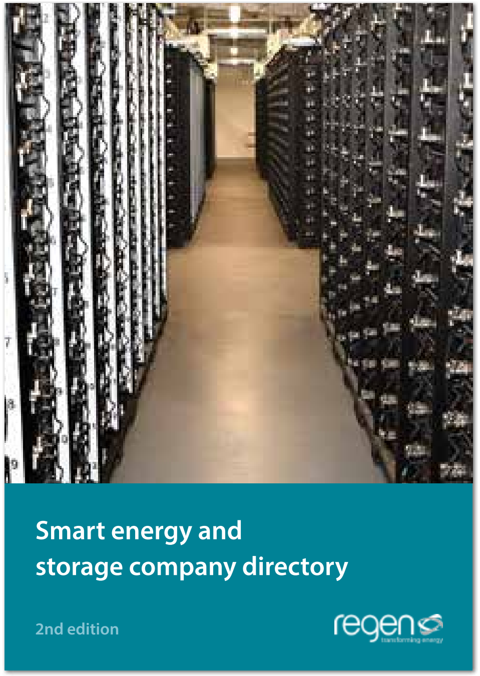
Energy Storage – Towards a commercial model (November 2016)



Guide to connecting electricity storage for communities and independent developers (February 2017)

WPD electricity storage animation (February 2017)





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About Regen

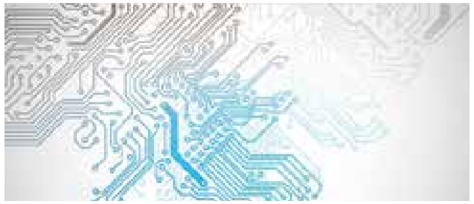
Regen passionately believes that sustainable energy has a vital role at the heart of a successful economy and thriving local communities. We are an independent not for profit that uses our expertise to work with industry, communities and the public sector to revolutionise the way we generate, supply and use energy.

regen transforming energy

Energy is the beating heart of our communities, an unseen web that binds us together. Radical change in such a critical system is not going to be easy. Our experience over 13 years is that we need entrepreneurial businesses who are forming partnerships and driving innovation; finance providers looking for new opportunities and regulators and utilities backing innovation. We also need the engagement and support of the local people and communities who rely on energy in every aspect of their lives.

We are ambitious on the scale of our impact. From our base in the south west of England we share our knowledge and experience of driving radical change in our energy system nationally and internationally.

RENEWABLE DEPLOYMENT



SMART ENERGY AND STORAGE

GRID AND NETWORK MANAGEMENT

DECARBONISATION AND ENERGY STRATEGY

HEAT

OFFSHORE RENEWABLE ENERGY

COMMUNITY ENERGY

WOMEN IN RENEWABLES

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